



EUROPE

Novel treatment paradigms and their transformative potential for the NHS

Insights for the ten-year plan for health

TECHNICAL REPORT

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Summary

The context: novel treatment paradigms as key for NHS reforms

Research and innovation is a fundamental part of the solution to NHS reforms and should not be seen as a second-order priority. As new ways of approaching treatments, novel treatment paradigms have the potential to fundamentally improve the quality and safety of patient care, as well as the efficiency and effectiveness of NHS services over the period of the NHS 10-Year Plan. Healthcare has always been a knowledge-intensive sector, and novel treatment paradigms build on a growing body of new foundational understandings of how the body works and of the mechanisms through which therapies can act. They also make use of new technologies, such as genetic tools and digital health technologies, devices and data. As we expand on later in this report, novel treatment paradigms include novel *biological* approaches to treatment, such as genomic medicine, synthetic biology, regenerative medicine, next-generation biologics, novel antimicrobials and alternatives to antibiotics, and chronotherapeutics. They also include novel *health technology* approaches to treatment such as technology, digital and data-enabled innovation for mental health, functional restoration and brain-computer interface technologies, robotic surgery, nanobots and smart pills.

The United Kingdom (UK) is globally respected in health and life sciences research, but the NHS's full potential to engage with developing, testing and adopting innovation, including novel treatment approaches, has

not been fully realised. There is a significant opportunity to make better use of the NHS as a unique base for testing novel solutions. The NHS currently has an overwhelming focus on immediate delivery and wider resource constraints, but as Lord Darzi's independent investigation of the NHS in England pointed out, research and innovation have a key role to play in NHS transformation. There is potential to better engage with the development and adoption of innovations in the NHS to integrate innovation into best practices. This has been demonstrated in some areas, for example, in the early adoption of novel cell therapies for blood cancers or international leadership in tackling antimicrobial resistance. However, more can be done.

Research aims and approach: making novel treatment paradigms a reality in the NHS

In this context, RAND Europe conducted a rapid study to better understand the potential of novel treatment paradigms to benefit patients and the NHS, to outline a vision of 'what good would look like' in relation to new treatment paradigms in the future, and key elements of a strategy that could help realise the vision. This study informed the Future State Programme, an initiative convened by Lord Darzi that contributed to wider efforts associated with the government's work on the 10-Year Plan for the NHS. The Future State Programme focuses on the role of innovation in general, as well as health promotion and protection, improved diagnosis and novel

treatment paradigms, and implementing service change.

The findings presented in the report are based on desk research and consultation with key stakeholders through key expert interviews. The report also benefited from exchanges with experts from Wellcome and GSK, RAND Europe's partners for the Future State Programme's theme on novel treatment paradigms. RAND Europe was funded by Wellcome to undertake this work.

A vision for the future of treatment through the NHS 10-Year Plan

In a vision for the future of treatment in the NHS, the development and adoption of novel treatment approaches could significantly benefit patients and the NHS through higher quality, more effective and more efficient care. Figure 1 highlights four core elements of this vision, showing what the future could be like within ten years and the horizon for the impact of the 10-Year Plan for Health being developed by the government. The contents that follow briefly elaborate on each of these elements, building on an analysis of the current impact and future potential from novel biological and health technology treatment paradigms elaborated on in the report.



Precise and personalised biological and health technology treatment approaches will improve patient outcomes and the efficiency and effectiveness of NHS services.



New types of therapeutic approaches will reduce the need for repeated treatments and hospitalisations, improve access to care and help address unmet needs.



Novel treatment approaches will help address major public health challenges, including those related to social inequalities.



Being a world-leading location to trial innovative treatments, alongside efforts to secure access to treatments, will deliver health and economic benefits.



1. Precise and personalised biological and health technology treatment approaches will improve patient outcomes and the efficiency and effectiveness of NHS services

Precision medicine focuses on developing treatments based on a better understanding of an individual's unique biology, and personalised medicine combines this with an understanding of other unique characteristics, such as lifestyle and environmental data. Precise and personalised medicine advances enable people to receive treatments that are likely to work better for them. Novel biological treatment approaches like genomic medicine use information about a person's genes to enable more precise and personalised therapies for diseases like cancer, sickle cell disease, and rare blood disorders. These approaches are also supported by better diagnostic testing approaches that genomics enables. Personalised treatments can also help improve the efficiency and effectiveness of NHS services. For example, using genetic information is already helping clinicians understand how a patient is likely to respond to a medication and is helping them make better decisions to ensure patients get effective medications that they can tolerate well in areas like cancer and HIV. This reduces wasting resources on medicines that do not work for specific patients or cause adverse drug reactions. There is a wealth of

opportunity to do this more broadly in the future and to achieve impact at scale within the next ten years.

Other types of treatments, like tiny biological compounds (nanomaterials), are also beginning to deliver treatments to specific places in the body more precisely, supporting more personalised care. There is potential for these novel treatments to be applied to innovation for a more diverse range of conditions and to benefit more people. Developments in personalised treatments in other areas, such as those related to the microbiome (a collection of tiny organisms living inside our bodies in organs like the gut and helping the body function), also have the potential to help tackle conditions for which there are currently limited options but major impacts on the NHS are likely beyond a ten-year horizon.

Advances in health technology can also help patients receive more precise and personalised treatment. For example, robot-assisted surgery uses robotic arms to help doctors perform surgeries and is helping the NHS deliver more precise operations, especially for patients with urological conditions. In the future, robot-assisted surgery could help the NHS deliver even more precise, less painful operations for a broader range of complex surgical procedures, minimising tissue damage and enabling faster recovery. However, further evidence is needed on issues such as long-term effects on patients and cost-effectiveness. Other health-technology-enabled treatment approaches, like 'smart pills' (pills with sensors or tiny cameras), are also being explored for their potential to more precisely deliver a medicine to a specific part of the gastrointestinal tract. However, research in this area is still relatively nascent.

More efficient and effective care can also be achieved by changing not what is given, but when. Some treatment approaches have already been found to be more effective when

they are timed to align with body rhythms, such as for asthma, cardiovascular diseases, and certain cancers. There is potential to explore this more widely, and unlike some other novel therapies, timing therapies better does not require a significant overhaul of existing NHS care pathways.



2. New types of therapeutic approaches will reduce the need for repeated treatments and hospitalisations, improve access to care and help address unmet needs

Treatments have been developed by applying engineering methods to modify or create new biological compounds (i.e. synthetic biology) to treat diseases, and this is already allowing patients to get a smaller number of treatments in a shorter time. One example is long-acting therapies called CAR-T cell therapies, which are already used for treating some blood cancers in the NHS. Other examples include long-acting therapies for HIV and COPD. In the future, there is potential to expand new cancer therapies such as CAR-T to a wider range of cancers that place an immense burden on patients and on NHS capacity. Other types of new therapies that build on advances in our understanding of human genetics also offer significant hope for better ways to treat conditions such as heart disease, dementia and muscular dystrophy and reduce the need for long-term and repeat needs for hospital-based care.

Regenerative medicine is another area of development that could reduce the need for repeated hospitalisations and treatments. Regenerative medicine uses techniques like stem cells (cells in the body that have an ability to turn into different types of cells) and engineering methods to develop treatments like artificially produced organs or tissue. Regenerative medicine applications have been tested in the NHS in areas like trachea

replacement, bone repair and hip replacement. If this could be scaled up in the future, for example, for treatment of hip fractures that cost around £2bn in expenses annually (across health and social care), significant savings could be achieved through reduced need for repeat surgeries and improved quality of life.

In addition, advances based on an understanding of viral, bacterial and human genetics are also enabling the development of new types of therapies that can help reduce unnecessary hospitalisations. For example, vaccines based on modified viral genetic material – messenger Ribonucleic Acid (mRNA) vaccines – were key to the COVID-19 pandemic response. New preventative and therapeutic uses for this technology are being researched for influenza and cancer. However, they may take more than ten years to translate into impact at scale, given the current state of development.

Innovative health-technology-enabled approaches to treatment are also helping tackle NHS waiting lists and areas of major unmet need, such as mental health treatment. The UK is at the forefront of developing new and improved mental health interventions that promise to deliver a far greater level of personalisation and targeted support. Digital technologies are emerging that can help patients access therapy remotely, with the support of mental health professionals or via self-guided apps, virtual reality and gaming applications. These include applications to treat depression, anxiety, insomnia and schizophrenia. In the future, digitally enabled mental health treatments could help overcome logistical and geographical barriers to providing care at a greater scale, and being able to access therapy via digital means can also help mitigate stigma and improve patient uptake. There are also new medications for some mental health conditions, such as Cobenfy, used for treating schizophrenia. If such medicines were to be approved by

regulatory authorities in the UK, based on evaluation evidence on cost-effectiveness and made available, they could help treat patients with a condition which has seen little significant progress in improving treatment options for decades.

Some new therapies may not address the needs of many patients but bring profound hope to those they do, potentially addressing disease areas that have historically been neglected in terms of progress. For example, new technologies can restore functions for some people with neurological and neuromuscular disorders. Already, cochlear implants in ears can restore hearing to profoundly deaf patients. Brain stimulation methods are emerging for conditions like depression and Parkinson's. In the future, the NHS could provide technological solutions to support immobile patients (e.g. those with quadriplegia) in controlling prosthetic limbs, wheelchairs and other tools, restoring some autonomy and enabling patients to communicate.



3. Novel treatments will help address major public health challenges, including those related to social inequalities

Drugs used to treat and manage conditions that affect large numbers of people, such as Wegovy or Ozempic (used to treat diabetes and obesity), are expensive at present but may be an effective way of addressing a major public health concern if affordability and pricing challenges are addressed. Research is examining the potential of this new class of drugs (called GLP-1 agonists) to treat depression and alcohol addiction in the future, and there is potential to consider these treatments alongside social interventions (such as those that could help tackle loneliness, social isolation, poverty or other social determinants of health). Other

types of novel treatments can turn off genes that cause health problems and have the potential for treating diseases like hepatitis B and liver damage more effectively. Some novel medicines are showing promise in liver disease more widely and in respiratory diseases such as COPD. Such novel therapies have the potential to provide new ways for the NHS to address societal health challenges, some of which are related to wider inequalities. These new treatment approaches could help improve people's wellbeing and ability to work, supporting wider efforts to ensure a fairer UK.

Other areas of innovation in treatment could also help tackle major public health challenges, such as antimicrobial resistance (AMR) and support care in the community, reducing the need for hospitalisations due to severe infections. Ongoing research and innovation show promise in finding new ways to fight infections and antimicrobial resistance more effectively, using methods like very small viruses (called bacteriophages, which are already used in some countries) to kill bacteria and improve our body's immune response or proteins made in a lab (monoclonal antibodies) to destroy bacterial and viral infections.



4. Being a world-leading location to trial innovative treatments, alongside efforts to secure access to treatments, will deliver health and economic benefits

Novel treatments bring health benefits for patients and can improve the quality and efficiency of care provided by the NHS and offer wider benefits. For patients, taking part in clinical trials can enable earlier access to new treatments. For the NHS, involvement in research is linked to high-quality care. Keeping people healthy can also improve productivity and tax revenue and reduce welfare costs. More broadly, health-related research and

development attracts investment that supports enterprise and job creation.

The United Kingdom is not as large a market for innovations as some other countries with different healthcare service financing and treatment pricing models and larger populations. However, the UK has significant and highly respected global strengths in life sciences and health technology research and development, and it has the NHS. The NHS is a unique resource in its potential to enable clinical trials of promising innovations by virtue of being a large publicly funded healthcare system with a large range of diverse healthcare provider organisations and access to diverse patient populations and data. There is a significant opportunity to make better use of the NHS as a unique base for testing novel solutions, with clinical trials also supporting efforts to give patients early access to novel treatments prior to wider-scale market authorisation, health technology assessments and NHS adoption. This could create a distinct competitive advantage for the UK in terms of attracting clinical trials, given that the UK cannot compete on cost (prices it can pay for medicines) with some other high-income countries.

From prospect to practice: seizing the opportunity and creating a supportive ecosystem

Responsible political choices and policy developments such as the 10-Year Plan will need to balance short-term priorities, such as dealing with waiting times for access to NHS services and crowded A&E departments, with a visionary commitment to take actions today that can help achieve medium and longer-term improvements in the NHS. In doing so, decision makers can build on the UK's existing strategic advantages to support care excellence and NHS sustainability well

into the future. All transformation efforts entail some upfront investment. There is a risk that prioritising short-term firefighting in the NHS comes at the expense of a bold vision for enduring and longer-term NHS excellence and sustainability. Without a policy approach that balances short-term priorities with longer-term sustainability and performance needs, it is possible that the problems we are trying to solve today will be ‘plastered but not healed’ and pushed further into the future.

Some novel treatment types are at more advanced stages of development than others and thus have a greater likelihood of impact on the NHS in a ten-year horizon.

Examples include more personalised and precise therapies for cancer, novel therapies for obesity, and digitally enabled mental health therapies. Other novel treatment paradigms are less advanced, such as chronotherapeutics (optimising timing of treatment), smart pills (small pills with sensors that can gather information in a person’s body to help diagnose a disease or deliver and track medication intake) and nanobots (molecule-sized robots designed to work inside a person’s body and perform tasks like delivering medicine precisely to where the disease is located or helping repair damaged tissues).

Other factors besides technological maturity will influence the timeframe and scale of impact that can be achieved. For example, the impact of different treatment paradigms will vary in terms of the diversity of the conditions that they could address and the types of patients that stand to benefit. The investment needed to accelerate the development and adoption of different new treatment approaches also varies in terms of the history of investment and the current state of UK infrastructure in specific fields, affecting the

scale of impact that is achieved over the time horizon of the 10-Year Plan. For example, the UK has historically invested more in areas like genomic medicine and synthetic biology than in areas like functional restoration or research and innovation related to the microbiome.

Overall, there is an opportunity to accelerate the pathway to impact patients and the NHS. This can be supported by focusing short and medium-term efforts on the testing, refinement and adoption of comparatively more mature treatment modalities that can achieve impact at scale within the next ten years. At the same time, emerging but high-potential areas of science and technology can progress with research and development (R&D) support, with a longer timeframe for impact on patients.

However, while some novel treatment paradigms are more mature and ready for impact than others, the biggest and most sustainable opportunities lie not in picking technology winners but in creating a supportive ecosystem for innovation in treatment in and around the NHS. An ecosystem of seven support mechanisms is the key platform needed to translate the potential of novel treatment paradigms into NHS practice. The support mechanisms represent opportunities to act and to create a sustainable platform for embedding innovation in treatment into the NHS. They have to do with the NHS workforce, data information and evidence environments; funding, commissioning and procurement; R&D governance and regulation; collaboration and coordination nationally and internationally; and patient and public involvement, engagement and participation. We have identified fifteen specific actions across the seven support mechanisms, as summarised in Table 1.

Table 1. Opportunities and actions to create a supportive ecosystem for research and innovation related to novel treatment paradigms in the NHS

 Opportunity 1: Workforce	1. Mainstream training on research and innovation related to novel treatment priorities into professional education and development of the NHS workforce (e.g. technical skills to deliver novel treatments). 2. Provide resources (e.g. leadership support, time, funding, enabling infrastructure) for NHS staff to support the adoption of novel treatments (e.g. via job structures and career pathways, ring-fenced time, reward and accountability for best practice).
 Opportunity 2: Data, information and evidence	3. Invest in a functional data access and sharing infrastructure in the health system, supported by interoperability and public trust. Better data access, sharing and linkage between different organisations in and around the NHS (e.g. innovators, academics, NHS staff) can enable research and innovation to develop new treatments and support their adoption. This needs to be secured using a mix of technical solutions that can help ensure data privacy and security, regulation and effective public engagement. There is an opportunity to build on more developed data environments already in place (e.g. genomics/multi-omics and genomic medicine). Using existing digital infrastructure (such as potentially the NHS App) could also help establish better ways of raising awareness, recruiting patients for clinical trials and enabling patients to decide what data they are happy to share. The newly announced partnership between the UK government and Wellcome to establish a new health data research service is a promising development. 4. Fund and steer an evidence pipeline for data on emerging treatments (such as promising developments in gene therapies, mRNA vaccines and digitally enabled therapies for mental health as some examples) from both clinical trials and real-world implementation studies. This can help secure accountable, evidence-based practice and inform the business case for NHS commissioning (e.g. long-term clinical and health economic impact data to inform optimal eligibility criteria and better data on the clinical and cost-effectiveness of robotic surgery).
 Opportunity 3: Funding, commissioning and procurement	5. Prioritise investments considering the levels of technology maturity and potential for impact related to disease burden or disease neglect innovation-wise, as well as the scale of improvement in health it can offer (including scope for long-term improvement). Using frameworks such as Technology Readiness Levels can help understand which types of novel solutions might be most ready for adoption in the NHS and which types of solutions in development need R&D support. 6. Use methods and tools such as horizon scanning, consensus exploration and target product profiles (TPPs, i.e. tools specifying the requirements an innovation needs to meet) to provide a clear demand signal to innovators and maximise the chances of new treatments meeting NHS needs. Set clear expectations for the adoption of new treatments in terms of both technical performance criteria and criteria related to cost and fit with NHS care pathways, with an advance commitment to support those that meet the requirements. In doing so, consider the need to balance national priorities and regional and local population-specific needs.

	7. Create longer-term budget cycles and commissioning approaches that focus more on combinations of products, technologies and services (i.e. a package of solutions) and less on commissioning individual products, technologies or services without consideration of their complementarities and interactions in delivering on desired outcomes. This could enable more strategic and realistic approaches to the commissioning of new treatments, helping fix funding flows and recognising value, including in the context of overall cost-savings for the NHS and other spheres of government over time. This could help mitigate the upfront investment needed for some treatments (e.g. long-acting gene and cell therapies and regenerative medicine, GLP-1 agonists for obesity, advanced medicines for respiratory diseases and robotic surgery). What could be commissioned centrally and what regionally and locally in a more solutions-focused approach merits attention. 8. Reinvigorate the clinical trial landscape, making the most of the potential of the NHS as a testbed for trials of innovations focusing on novel treatment paradigms.
 Opportunity 4: R&D governance and regulation	9. Ensure a more streamlined, single overarching R&D approval process (learning from efforts to streamline ethics approval processes) across the NHS, alongside a national training programme for staff working in R&D offices. 10. Establish clear and flexible regulatory processes for new treatments (e.g. standardised protocols for manufacturing and preparation of antimicrobial phages, regulatory sandboxes in synthetic biology, regulation related to neurotechnology and new forms of data and the potential for influencing cognition).
 Opportunity 5: Physical infrastructure	11. Ensure that the underpinning physical and technical infrastructure is in place to scale priority new treatments (e.g. to deliver CAR-T therapies or mRNA vaccine manufacture), including functioning basic IT systems, hardware and Wi-Fi and safe physical environments.
 Opportunity 6: Collaboration and coordination	12. Establish a cross-sector governance and coordination arrangement for funding and orchestrating initiatives that can support the pathway from R&D through to adoption, scale and spread. This should include closer coordination between regional and national efforts, between industrial and health policy bodies and funders, and between R&D governance, regulatory and health technology assessment bodies. 13. Create a community of practice (nationally and internationally) around novel treatment paradigms involving clinical, health services, biomedical, engineering and data science expertise, as well as public and patient voices and industry. In key strategic areas (e.g. genomic medicine, synthetic and engineering biology, regenerative medicine), the UK already has established collaborations that provide a basis to build new collaborative efforts driving progress in research and innovation and its adoption.



**Opportunity 7:
Patient and public
involvement,
engagement and
participation**

14. Pursue timely public and patient consultations and engagement around potential questions (e.g. ethical considerations, equality in access, eligibility). Personalised medicine requires patients to commit to data sharing with confidence, for which an unfortunate legacy of past concerns needs to be overcome.
15. Address inequalities by ensuring the relevance of new treatments for a full range of Britain's population and access to them. Consider population diversity in determining what research and innovation is prioritised and how it is conducted (i.e. with whom as participants or patient and public involvement advisors).

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Abbreviations

AI	Artificial Intelligence
ADCs	Antibody-Drug Conjugates
AMR	Antimicrobial Resistance
BCI	Brain Computer Interface
CAR-T	Chimeric Antigen Receptor T-cell
COPD	Chronic Obtrusive Pulmonary Disease
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
DBS	Deep Brain Stimulation
DNA	Deoxyribonucleic Acid
EEG	Electroencephalography
EGF	Edinburgh Genome Foundry
EU	European Union
EVA	Early Value Assessment
FMT	Faecal Microbial Transplantation
GI	Gastrointestinal
GLP-1	Glucagon-Like Peptide 1
HIV	Human Immunodeficiency Virus
HTA	Health Technology Assessment
IAPT	Improving Access to Psychological Therapies
MHRA	Medicines and Healthcare Products Regulatory Agency
mRNA	Messenger Ribonucleic Acid
NAP	National Action Plans
NHS	National Health Service
NICE	National Institute for Health and Care Excellence
NIHR	National Institute for Health and Care Research
PPIE	Patient and Public Involvement and Engagement
RSV	Respiratory Syncytial Virus
QALY	Quality-Adjusted Life Year

R&D	Research and Development
tDCS	Transcranial Direct Current Stimulation
TEC	Technologically Enabled Care
TIL	Tumour-infiltrating Lymphocytes
TTPs	Target Product Profiles
UK	United Kingdom
UKRI	UK Research and Innovation
US	United States

Chapter 1. Introduction: novel treatment paradigms as key for NHS reforms

The context

The development of the NHS 10-Year Plan creates an opportunity to integrate bold, creative thinking into planning for the future of the health service and to place the commitment to excellence in care on a sustainable footing, fit for the present and the future. This includes an opportunity to support the development and adoption of novel treatment paradigms in the NHS. Novel treatment paradigms (i.e. new approaches to treatment) should be central to the NHS 10-Year Plan, supporting its ambitions to deliver NHS reforms and societal benefit. Not doing so would be a missed opportunity and would risk the UK being left behind in relation to global developments, population health outcomes, and broader societal and economic prosperity. Innovative treatments can unlock opportunities to improve care quality, safety and efficiency.

Novel biological and health technology treatment paradigms are creating opportunities to rethink the future of NHS care to improve care quality, safety, cost-effectiveness, and patient outcomes and experience, as well as to contribute to the economy and attract investment into the NHS and health and innovation system around it.

Scientific and technological progress is driving advances in both novel *biological* treatment paradigms and novel *health-technology*-based treatment (see Table 2 for explanations). Additionally, many novel treatment types build on interrelated scientific and technological advances. For example, the field of synthetic biology can include advances in genomic

medicine. Many of these advances are enabled by the convergence of research disciplines and innovation fields (e.g. biological sciences, engineering, computer science, health services research), creating opportunities for more predictive, personalised and targeted treatments (Figure 1). In addition, some emerging paradigms do not rely on developing novel technology and products but rather on optimising treatment protocols, like the timing of their administration (i.e. chronotherapeutics).

The UK has a globally highly respected health research system and benefits from vibrant life science and health technology clusters, as well as strong networks between academia/ research institutes, the NHS, and industry. It has nevertheless been historically slow at translating science and technology advances into products, technologies and health service models that benefit the NHS and patients.

This is partly attributable to challenges in adapting regulation to scientific and technological changes and the affordability of innovations, with the NHS seen as a particularly cost-sensitive system internationally. There is a need to create an ecosystem where research and development, including clinical trials, can contribute to technology advances and timely access to them through NHS adoption.

An immense untapped potential exists to bring innovation, including novel treatment paradigms, to patients in timely ways. This potential has been demonstrated in some areas but needs to become embedded into the fabric and ways of working in the NHS more widely. For example, the UK was the first country in Europe to secure access to CAR-T therapies for patients with

lymphoma.¹ The ability to lead on innovative payment models has also been illustrated in areas such as antimicrobial resistance (AMR) subscription models.² Before that, UK research played a leading role in discovering monoclonal antibodies (proteins made in the lab that attach to harmful cancer cells and viral or bacterial infections and help the immune system destroy them and fight off disease).³ This illustrates the potential to both develop and adopt innovation and to ensure conducive regulation and commissioning. For example, the MHRA has the potential to deliver innovative and lean regulation, fast-tracking promising innovations in robust ways and is introducing several initiatives to help achieve this (e.g. Innovative Access and Licensing Pathway,⁴ Project Orbis that aims to efficiently review novel cancer drugs,⁵ MHRA International Recognition Procedure which allows the MHRA to consider international regulatory decisions and evidence).⁶ The National Institute of Health and Care Excellence (NICE) is highly respected for its health technology assessments, and various countries use NICE outcomes as reference points for their own recommendations and guidelines.^{7,8} However, regulation is still seen to be cumbersome and bureaucratic, and the full potential for regulatory innovation has yet to be realised.

To make the most of the opportunities ahead, the health and innovation ecosystem must evolve to generate, develop, evaluate and adopt new treatment paradigms in a way that allows the NHS to make the right choices in a timely way and with the right support mechanisms in place. A health and innovation ecosystem may sometimes be seen as a somewhat abstract concept. In this report, we consider it to be the constellation of support mechanisms that enables a health system to develop and deliver on research and innovation-informed best practices. These

support mechanisms can span diverse policies and practices related to issues such as the workforce, data and physical infrastructure, information and evidence environments, institutional relationships, governance, regulation and evaluation and patient and public engagement. As we will discuss in this report, there are practical ways to build a supportive system for accelerating advances in research, science and technological developments and bringing benefits to patients and the NHS.

Research aims and approach

RAND Europe was asked to conduct a rapid project (from January to the end of February 2025) aiming to identify opportunities and what the future could look like in relation to novel treatment paradigms in the NHS. This work was invited as part of the Future State Programme convened by Lord Darzi, contributing to developing the Government's 10-Year Plan for the NHS. The Future State Programme focuses on the role of innovation in general, as well as health promotion and protection, improved diagnosis and novel treatment paradigms, and implementing service change. Our contribution focused on novel treatment paradigms, and we worked in collaboration with experts from Wellcome and GSK as partners within the Future State Programme for this theme. This report provides a compendium of the underlying evidence and analysis that contributed to a short discussion paper for the Future State Programme.

This report primarily draws on desk research based on a targeted and focused scoping review of the literature and stakeholder consultation (n=15 key informant interviews) to outline a vision of 'what good looks like' in relation to novel treatment paradigms in the NHS, the transitions in the health system that are integral to this vision, and key elements of

a strategy that could help realise the vision. Interview evidence is referenced by code Int x (where x=interview number). It also draws on a long-standing body of work on innovation and the NHS conducted by RAND Europe researchers,^{9–11} including a recent report commissioned by Wellcome to establish a vision for science and innovation in the NHS as part of efforts to inform the 10-Year Plan.¹² Key insights are derived through desk research cross-analysis and synthesis, team and collaborator meetings, and based on thematic analysis.

Limitations

When interpreting the insights presented in this document, the following limitations should be considered. The research underpinning this study was conducted over a period of seven weeks. As a result, not all potentially relevant literature on novel treatment paradigms has been covered, nor can we claim to have consulted all relevant experts. However, we are confident that the combination of the diversity of experts who contributed to this work, the diversity of literature covered and insights from many years of RAND Europe research on innovation in health systems and health services transformation, including in the NHS, provides a well-rounded evidence base upon which insights have been drawn.

Organisation of report

This report is organised as follows:

- Chapter 1 introduces the background and context of this project and its associated research aims and approach.
- Chapter 2 discusses the current impacts and the future potential of diverse novel biological treatment paradigms (i.e. genomic medicine, synthetic biology, regenerative medicine, next-generation

biologics, novel antimicrobials and alternatives to antibiotics and chrono-therapeutics) and diverse health technology paradigms (i.e. technology, digital and data-enabled innovation in mental health, functional restoration and brain-computer interface technologies, robotic surgery, nanobots and smart pills).

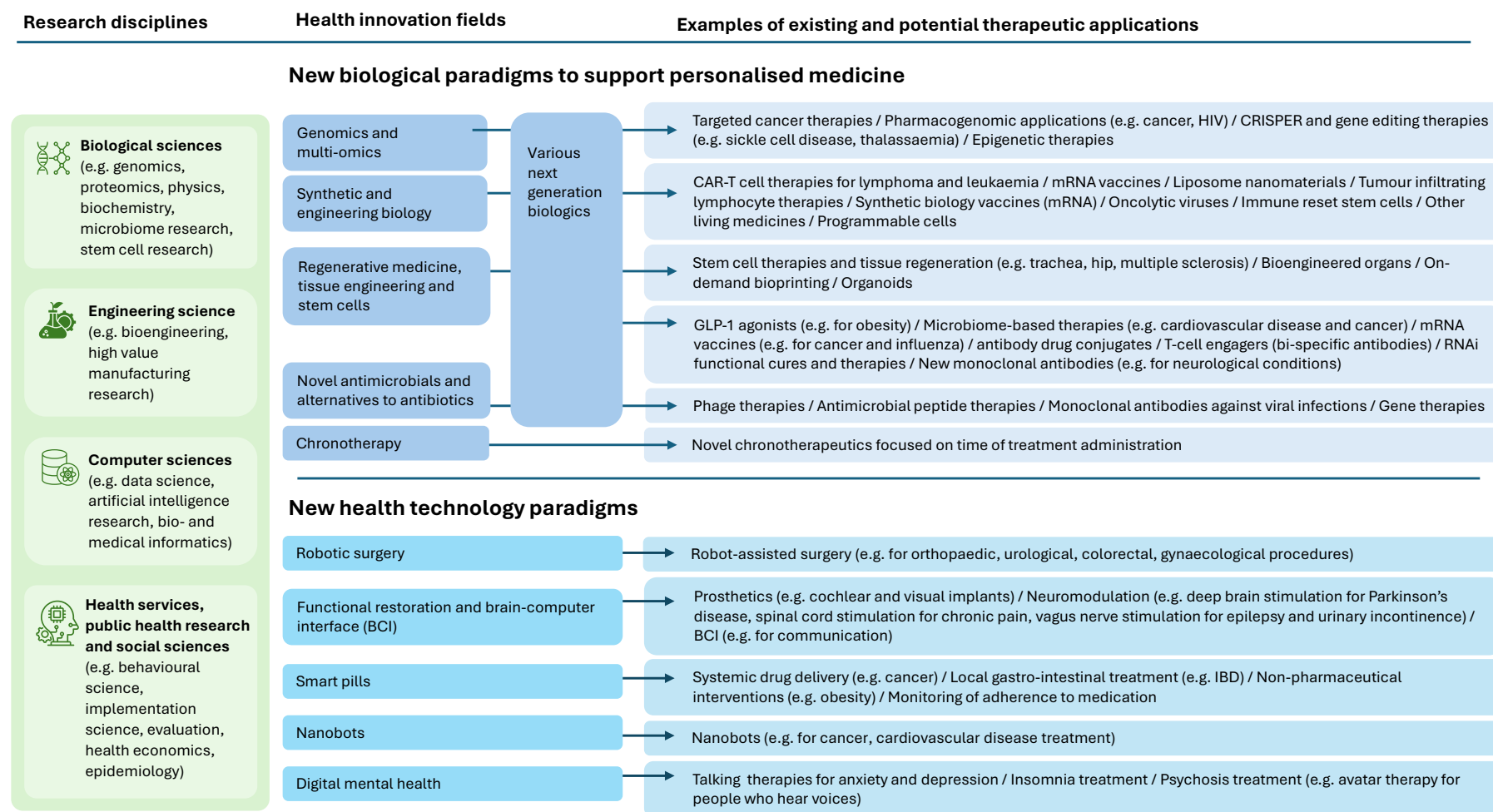
- Chapter 3 reflects on the findings and outlines a vision for the future of novel treatment paradigms in the NHS, highlighting the key types of benefits that could be realised and the transitions in practices that would accompany the realisation of this vision.
- Chapter 4 considers how we get from where we are today to where the NHS could be in the future, i.e. what is needed to achieve the vision for novel treatment paradigms in the NHS.
- Chapter 5 offers some reflective concluding remarks.

Table 2. Novel biological and health technology treatment paradigms that can transform the quality, safety, efficiency and effectiveness of NHS care and patient and population health

Type of novel treatment approach/paradigm	Explanation
 Genomic medicine	Genomic medicine uses information about a person's genes (DNA) to diagnose, prevent or treat diseases like cancer and rare diseases. Genomic data can be coupled with other types of information (e.g. data on patient conditions, treatments and other biological data) to develop more personalised, precise and effective treatments. A branch of genomic medicine – pharmacogenomics – helps scientists understand how a person's genes affect their response to medications. This helps doctors make better decisions about which treatments to give a patient to improve outcomes, reduce adverse drug reactions and side effects and could prevent NHS resource wastage on treatments that do not work.
 Synthetic biology	Synthetic biology uses engineering methods to modify biological organisms to give them new functions or create new types of biological compounds. It can be used to develop treatments that work better for patients and improve their survival and quality of life. It creates prospects to treat diseases that are currently very hard to treat (for which there are no effective treatments or where treatments come with severe side effects), like some cancers and genetic disorders, and to develop treatments quicker or more efficiently.
 Regenerative medicine	Regenerative medicine creates prospects for using techniques like stem cells, engineering of tissue and gene therapies (which use tools like CRISPR to edit, alter or replace faulty genes) to repair, replace or restore damaged tissue (e.g. for patients with hip fracture), to stop the body rejecting transplanted organs to enable more success in transplant procedures, and to help patients heal.
 Next generation biologics	Next-generation advanced medicines are made from modified cells, organisms or biological compounds to help treat diseases more effectively. They include therapies to fix genes or switch them on and off (i.e. epigenetic therapies) to treat diseases like cancer; new treatments that restore a healthy gut microbiome (e.g. helpful bacteria in the gut) to help fight infections and keep the immune system strong; or novel formulations of medicines that control blood sugar levels and help treat major public health challenges like obesity (e.g. GLP-1 agonists).
 Novel antimicrobials and alternatives to antibiotics	Novel antimicrobials and alternatives to antibiotics are giving us opportunities to find new ways to fight infections and tackle antimicrobial resistance, using methods like very small viruses (called bacteriophages) to kill bacteria or improve the body's immune response.

 Chronotherapeutics	Chronotherapeutics is an approach to treatment that considers our body's natural rhythms to identify the best times of day to give a person medication to make it more effective and to reduce side effects.
 Technology, digital and data-enabled innovation in mental health	Innovation in mental health treatment is allowing us to use digital technologies (e.g. internet, apps, chatbots, avatars) to deliver treatments for conditions like depression, anxiety and insomnia through talking therapies or other online therapies that help people change unhelpful thoughts and behaviours. This helps people get the care they need in timely ways and helps manage long waiting times for NHS mental health services.
 Functional restoration and brain-computer interface	These are novel techniques that can help people regain the abilities they have lost. They include technology that allows a person's brain to communicate via computers or to give people physical (e.g. controlling prosthetic limbs) or cognitive abilities (brain stimulation to treat depression), improving quality of life.
 Robotic surgery	Robotic surgery allows doctors to use machines with robotic arms to help perform operations very precisely to support better surgery and less painful and faster recovery for patients.
 Nanobots	Nanobots are molecule-sized robots that are designed to work inside a person's body and perform tasks like delivering medicine precisely to the cells and tissues where the disease is located or helping repair damaged tissues.
 Smart pills	Smart pills are very small tablets with sensors or cameras that can gather information in a person's body to help diagnose conditions, monitor treatment effectiveness or deliver medicines in ways that are easier for patients (e.g. pills instead of injection).

Figure 1. Research disciplines and innovation fields enabling novel treatment paradigms



Chapter 2. Novel biological and health technology treatment paradigms: current impact and future potential

The contents below discuss examples of current benefits and future potential of novel biological and health tech treatment paradigms for patients, the NHS and the UK more broadly. They illustrate the opportunities the NHS has to revolutionise patient access and outcomes, improve NHS quality of care, reduce wastage of resources and realise short-term savings in some areas with the potential for longer-term savings in others. Investment in novel treatment paradigms also holds significant scope to contribute to economic benefits including (e.g. attracting clinical trials revenue), wider benefits through enterprise, job creation, labour productivity and societal benefits in relation to the UK's position as a leader in healthcare innovation and excellence on a global stage.

Novel biological paradigms

In what follows, we expand on the transformative potential for patients and the NHS of novel treatment paradigms in (1) genomics and multi-omics for personalised medicine, (2) synthetic and engineering biology, (3) next-generation biologics, (4) regenerative medicine and tissue engineering, (5) innovation to tackle antimicrobial resistance and (6) chronotherapy. It is important to flag that the boundaries between some of these fields are fluid and the fields interrelated. For example, genomic medicine, synthetic biology and regenerative medicine can all input into next-generation biologics. Similarly, gene editing can inform the

development of treatments involving synthetic biology (e.g. CAR-T therapies for cancer).¹³



Genomics and multi-omics for personalised medicine

Genomics and **multi-omics** form key foundations in the field of **personalised medicine**. **Genomic data**, or information on individual DNA, including genetic variations and biomarkers, can be coupled with other types of information to develop more personalised, precise and effective treatments.¹⁴ Other emerging sources of data for personalised medicine are information on protein expression, defined by the field of **proteomics**, as well as combined information on gene expression, coding and regulation, also known as **transcriptomics**.¹⁵ Understanding the intersection of genomic, proteomic, transcriptomic, and other data forms the field of **multi-omics**, which aims to understand how environmental and genetic factors manifest in the form of disease.¹⁵ As an application of the data and science on multi-omic factors, **genomic medicine** uses information about a person's genes (DNA) to diagnose, prevent or treat diseases like cancers and rare diseases.¹⁶ One specific application of genomic medicine is **pharmacogenomics**, which helps us understand how a person's genes affect their response to medications.^{17,18} Another application is in the field of **epigenetics**, which works by changing how genes are regulated to mitigate the impacts of their expression.¹⁹

Developments in genomics and multi-omics have helped provide access to life-saving treatments, promote health system efficiencies, and generate economic growth in the UK.

Treatments currently in use within the NHS target high-priority diseases, both from a disease burden and an inequalities standpoint. The UK has begun implementing targeted breast cancer therapies,^{20–22} and CRISPR-gene editing therapy for sickle cell and transfusion-dependent β thalassaemia, with the latter receiving a recommendation (with managed access) from NICE in September 2024.²³ Innovation in pharmacogenomics has helped clinicians make better-informed decisions about which treatments to administer to patients, to reduce adverse drug reactions and improve treatment effectiveness (e.g. in cancer^{24–27} and HIV^{28,29}). This can help reduce medicine wastage and save the NHS resources. Advances in genomic medicine have also led to distinct economic benefits for the UK. The UK genomics sector's turnover was £3.6bn in 2021/2022,³⁰ and the British Industry Association estimates a market capitalisation of £50bn by 2040.³¹ The Association of British Pharmaceutical Industries' analysis shows a doubling in genomics-related jobs between 2016/2017 and 2021/2022.³⁰

Advances in genomics and multi-omics have created opportunities to identify novel disease biomarkers and inform more personalised medicine across preventative, predictive and therapeutic applications.

The UK has strong foundations and has made significant advances in genomic medicine in the NHS. Organisations such as Genomics England, UK Biobank, the NHS Genomic Medicine Service (GMS), and Our Future Health and institutions like the Wellcome Sanger Institute and Wellcome Genome Campus have been key to progress in this field, including initiatives such as the Deciphering Developmental Disorders collaboration.³² Through the discovery of

new genes associated with developmental disorders, the programme has led to improved patient management and support as well as the advancement of clinical knowledge around these disorders, helping to improve clinical practice.¹² Organisations and programmes such as these have generated benefits for patients, the health service, and the economy – as well as for the wider research community, including those studying emerging fields such as proteomics. This has created opportunities for further benefits in the future.

A vision for the future of genomics and multi-omics includes scaled-up genomic medicine in the NHS, leading to more patients across settings in the UK benefiting from access to science and technology advances in this area.

In the future, patients would have access to improved diagnosis and more tailored and targeted therapies, leading to better patient outcomes, fewer side effects, reduced needs for long-term repeated health service interventions and even cures for diseases. New therapeutic approaches under development, which include epigenetic therapies, proteomic interventions that target malfunctioning proteins and gene-editing therapies that fix faulty genes, have the potential to lead to more effective treatments and improved progression-free survival. This progress could benefit patients with cancer, heart disease and dementia (Int 2).^{33–36} Genomic and multi-omic medicine advances could also reduce the need for hospital-based care by enabling earlier intervention and long-acting and curative treatments, as well as facilitate care in local settings (e.g. fast turnaround long-read sequencing technology in primary care).¹²

Box 1 highlights examples of the current impact and future potential of genomic and multi-omic medicine.

Box 1. Genomics, multi-omics and personalised medicine: current impact and untapped potential



CURRENT IMPACT EXAMPLES

Achieving better patient outcomes through improved diagnosis informing more effective, targeted therapies:

- PARP inhibitors enhance patient outcomes in cancer, minimise unnecessary treatments and support preventive measures.^{21,22}
- More precise diagnosis enabled by genetic sequencing of patients with glioblastoma (an aggressive and deadly brain tumour)³⁷ enables more tailored treatment plans and early access to novel medicines through participation in trials.
- Polygenic risk scores for cardiovascular disease are informing novel treatment approaches to treating patients.³⁸

Avoiding adverse drug reactions and wastage of NHS resources, enabling cost savings:

- Pharmacogenomic applications are reducing medication wastage in the NHS and helping patients receive an effective treatment³⁹ that does not cause adverse drug reactions (ADR) in areas ranging from oncology^{24,25,27} to optimising HIV treatment.²⁸ This approach could save substantial NHS resources. ADRs and unusable treatments are estimated to cost the NHS approximately £2bn annually.¹⁸

Reducing the need for repeated treatments and fewer side effects:

- GMS enabled the introduction of the first gene-editing treatments in the NHS (CRISPR-based therapy for treating sickle cell and transfusion-dependent β thalassaemia in 2023).²³



UNTAPPED POTENTIAL FOR NHS AND PATIENT BENEFIT

Scaling and spreading existing NHS genomic medicine therapies to support equitable access for patients across the UK.⁴⁰ This would enable more patients to benefit from more targeted therapies as well as more precise diagnoses to enable more effective treatment.

Developing new life-saving treatments based on a better understanding of disease progression enabled by better linked genetic, proteomic and behavioural data paving the way for further personalised treatment developments.⁹¹

Epigenetic therapies for more effective treatments, enhanced immune response and improved patient outcomes, including progression-free survival in areas like ovarian cancer, cervical cancer, and neuroblastoma.^{41–43} Oxford Nanopore Technologies is aiming to create the world's first comprehensive dataset of epigenetic modifications to help reveal the root causes of diseases like cancer, heart disease, and dementia, which could lead to new diagnostic and therapeutic strategies.³⁴

Novel treatments informed by proteomic data and a better understanding of interactions between genes, proteins and the environment in the development and progression of diseases. For example, research on the association between proteins and disease conducted within the UK and internationally, using UK Biobank data,^{35,36} is already supporting breakthroughs in understanding biomarkers for Alzheimer's disease and dementia (Int 2)³³ and creating new prospects for the development of innovative therapeutic interventions. Proteomic advances may help us better understand disease than genomic data, including in the context of the impacts of environmental stressors and considering genetic interactions with the environment (Int 2).

Novel gene therapies with the potential to reduce the number of treatments needed and their side effects. CRISPR and gene editing technologies are being trialled across the world in new areas with limited current treatments and/or high disease burdens such as hereditary transthyretin amyloidosis,^{44,45} types of muscular dystrophy,⁴⁶ HIV and HBV,^{47,48} and cystic fibrosis⁴⁹ (Int 10). As of August 2024, nearly 4,000 clinical trials concerning gene therapy or gene editing have been completed globally.⁵⁰ Depending on the study outcomes, the future could see new opportunities to improve treatment options for patients.



Synthetic and engineering biology

Synthetic and engineering biology (closely related fields and often synonymously used terms) are opening up new treatment frontiers by combining insights from biology, engineering and computer science. This field illustrates the immense potential of technology convergence to benefit patients and advance

health services. The design and engineering of biological systems to perform tasks such as sensing, responding to changes in the environment or producing specific molecules started growing rapidly in the 2010s, with the emergence of technologies like CRISPR for genetic editing, low-cost DNA synthesis, next-generation DNA sequencing, high-throughput genetic screening and new computational tools.^{51,52} Many areas of therapeutic progress

have relied on synthetic biology, benefiting from discoveries in fields such as genomics, systems biology, computational biology and physics (e.g. CAR-T therapy for cancer treatment⁵³).

Strategic government support and academic excellence have resulted in the UK being one of the global leaders in synthetic biology research.

The UK already has strong foundations, national and international collaborations in synthetic biology through investments such as The UK's Synthetic Biology for Growth programme (2014–2022)⁵⁴ and policy support for bolstering the sector. For example, the UK Synthetic Biology Strategic Plan 2016⁵⁵ outlined principles to accelerate industrialisation, maximise innovation capabilities, build an expert workforce, create a supportive business environment, and foster national and international partnerships, positioning the UK as a leader in synthetic biology and life sciences innovation.⁵⁴ Recognised as a critical technology in the government's 2023 Science and Technology Framework,⁵⁶ engineering biology is a focus area for building strategic advantage. In the National Vision for Engineering Biology in 2023, the UK government pledged to invest £2bn over the next ten years.⁵⁷ Additionally, various business support programs and accelerators, such as SynbiCite and the Connecting Capability Fund, aim to foster innovation and commercialisation.⁵⁴ UK remains one of the leaders of the life science sector in terms of investment in Europe, with £18.6bn corporate investment in 2020.⁵⁸

Synthetic biology-related advancements such as CAR-T therapies for cancer, messenger Ribonucleic Acid (mRNA) vaccines for infectious diseases, and nanomaterials are already having an impact on the NHS at a varying scale. For example, CAR-T cell therapies for cancer enable a better patient experience, long-term outcomes, and shorter treatment

durations for lymphomas and leukaemia (INT4). England was the first European country to deliver CAR-T therapy through its national service in 2018,⁵⁹ and multiple types of CAR-T therapies are currently approved by MHRA for adults and some children with certain types of lymphoma and leukaemia not responding to other treatment.⁶⁰ Synthetic biology also played a major role in developing mRNA vaccines for Covid-19.⁵² Development of nanomaterials and lipid nanoparticles is also allowing enhanced delivery, reduced toxicity and preserved effectiveness of new synthetic biology drugs (e.g. Patisiran for hereditary transthyretin amyloidosis⁶¹).

There is much more potential to develop new treatment modalities and benefit patients across a wider range of diseases and at a greater scale in the future.

Examples of other advances and future potential include next-generation CAR-T therapies for solid tumours⁶² (INT4), tumour infiltrating lymphocytes for metastatic solid cancers,⁶³ the development of novel preventative (e.g. influenza⁵³) and treatment vaccines (e.g. cancer⁶⁴) (Int 7), wider applications of oncolytic viruses to destroy cancer cells,⁶⁵ programmable cells to target tumours,⁶⁶ bacteria for engineering therapeutic molecules⁶⁷ and stem cell-based therapies for autoimmune diseases.⁶⁸ Many of these treatments could have a shorter duration and prevent the need for further treatment due to high effectiveness (INT4). There is also potential for synthetic biology to support more sustainable and cost-effective drug development.⁵²

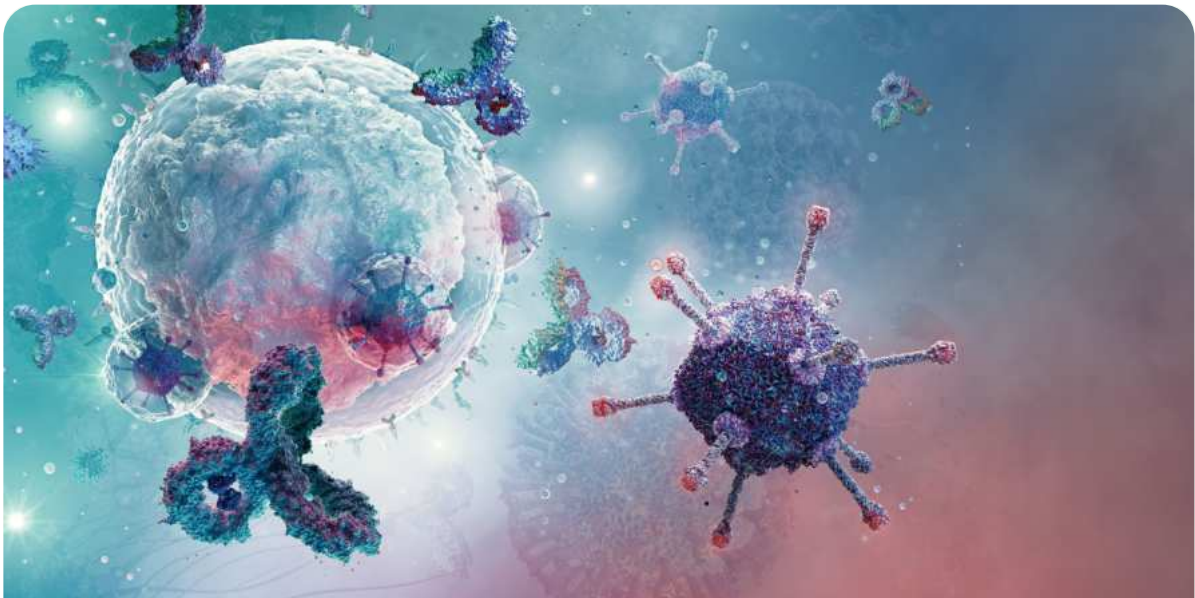
Current infrastructure and know-how in the UK could help catalyse further progress in developing novel treatments that build on synthetic biology for the benefit of patients as well as the wider economy. The majority of investment in synthetic biology is for healthcare applications, according to the World Economic Forum.⁶⁹ The UK hosts numerous

research centres and hubs, including the Imperial College Centre for Synthetic Biology,⁷⁰ Bristol's engineering biology community and facilities like BrisSynBio⁷¹ and the Bristol BioDesign Institute⁷² and the Edinburgh Genome Foundry⁷³ (EGF), which offers end-to-end design, construction, and validation of genetic constructs. Engineering biology could unlock a significant global economic impact, estimated between \$2 to \$4 trillion annually by 2030 to 2040, by transforming a wide range

of sectors beyond health, such as industrial biotechnology, materials, energy and food.⁷⁴ In the UK, over 1,800 businesses are already engaged in modern industrial biotechnology, contributing significantly to the economy and employing thousands.⁷⁴

Box 2 highlights examples of the current impact and future potential of synthetic biology treatment.

Box 2. Synthetic biology: current impact and untapped potential



CURRENT IMPACT EXAMPLES

Better patient experience and outcomes in cancer care through CAR-T cell therapies:

- CAR-T cell therapies for lymphomas and leukaemias⁷⁵ benefit patients in terms of long-lasting effects, short treatment time,^{76,77} faster recovery time (compared to chemo and radiotherapy),⁷⁶ and effectiveness for cancers resistant to other treatments.^{76,78} England was the first European country to adopt a national service for delivering a CAR-T,⁵⁹ and four types of CAR-T therapies (as of February 2025) are used in the UK for adults and some children with specific types of lymphoma and leukaemia not responding to other treatment.⁷⁹

Novel vaccines for infectious diseases:

- Synthetic biology underpinned the development of SARS-CoV-2 vaccines, and lipid nanoparticles were instrumental in delivering mRNA vaccines against COVID.⁵²

Nanomaterials relevant to synthetic biology innovations that can enable better-targeted drug delivery, reducing toxicity and preserving drug effectiveness (Int 6):

- Liposome nanomaterials for DNA/RNA drug delivery systems. Liposomes provide targeted drug delivery while reducing toxicity and protecting drugs from degradation. The NHS approved an RNA-based therapy to treat some forms of hereditary transthyretin amyloidosis with polyneuropathy⁶¹ (a rare disease with limited treatment options).



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Novel, more effective, precise and safe synthetic cancer therapies:

- Next-generation CAR-T therapies and expanded application to diverse solid tumours (90% of all cancers) and immunotherapy. In the UK, multiple clinical trials of CAR-T cell therapies are ongoing⁸⁰ Work is underway to enhance CAR-T precision, effectiveness, and safety⁸¹ with advanced genetic techniques.
- Tumour-infiltrating lymphocyte (TIL) therapy holds the potential to improve the treatment of metastatic solid cancers using T cells harvested from the patient's tumour, especially for patients not responding to other therapies. One treatment (Lifileucel) approved by the FDA for treating advanced (metastatic) melanoma involved Royal Marsden NHS Foundation Trust in clinical trials.⁸² Applications being explored in areas like liver, ovarian, lung, skin and testicular cancers.⁸³
- Expanded use of oncolytic viruses to inform new cancer treatment paradigms: A modified herpes simplex virus (HSV) that infects tumour cells and promotes their destruction for subsets of patients with melanoma has been recommended by NICE for some cases of metastatic melanoma.⁸⁴ Research into oncolytic viruses could lead to new therapeutic applications.

More effective preventative and therapeutic vaccines for infectious diseases and cancer:

- Synthetic biology is being explored for developments such as creating a universal influenza vaccine (that would not need updating every year).⁸⁵ While it would be more preventative than therapeutic, research is also ongoing in therapeutic applications like cancer vaccines.^{64,86}
- Other applications with the potential to develop treatments for areas of unmet need include living medicines (bacteria engineered to produce therapeutic molecules in response to disease signals⁶⁷), immune reset stem cells for autoimmune diseases⁶⁸ and programmable cells engineered to target tumours.⁶⁶



Regenerative medicine, tissue engineering and stem cells

Developments in regenerative medicine are presenting opportunities to heal or replace damaged tissues and organs. This field builds on and encompasses related innovations – for example, the use of **cellular reprogramming** to generate stem cells from other cells in the body (e.g. turning skin cells into stem cells) and **the use of stem cells** to enable **tissue engineering** and the development of **bioengineered organs**. Advanced applications of these technologies include **on-demand bioprinting**, using living cells and materials to ‘print’ more precise tissues and organs customised to a specific patient, and the development of **lab-grown mini-organs** or **organoids** which mimic organ function and behaviour.

Regenerative medicine applications in the NHS are still emerging. However, progress is being made to improve patient quality of life, reduce the need for ongoing treatments, and eventually reduce health system and societal costs associated with ill health (Box 3). For example, researchers from the University of Southampton have made notable progress in developing approaches to hip replacements based on regenerative medicine, using stem cells to bind titanium hip replacements to the rest of the body. Alongside generating better patient outcomes, this has the potential to create substantial benefits for the health service. The NHS has around £2bn in expenses related to hip fractures annually, and the stem-cell-based approach could save up to £34.8m per year.^{87,88} Moreover, improved outcomes from better hip replacements could also improve patient economic activity post-surgery.^{87,88} This is just one example of the potential of regenerative medicine to benefit patients and the NHS as scientific progress continues.

Work to support regenerative medicine research and translation in the UK and abroad is ongoing.

In 2017, the House of Commons Science and Technology Committee report on regenerative medicine was a key impetus for change.⁸⁹ The UK Regenerative Medicine Platform (RMP) was established in 2013 to advance scientific and technological progress and to address bottlenecks in regulation, manufacturing and cost as the main barriers to scale in the NHS.⁹⁰ The establishment of the RMP was accompanied by work within established organisations, such as the UK Cell and Gene Therapy Catapult, to pursue regenerative medicine research, development and scale-up to ensure that research, manufacturing, and commissioning of regenerative medicine solutions were up to date to support UK ambitions in regenerative medicine (Int 3).⁸⁹ Progress within UK institutions, including the NIHR, NICE and the MHRA, has been ongoing but slow since this point, a product of the gradual pace of technological change, scrutiny towards the quality of evidence in this area, and barriers to UK-based investment, R&D and commissioning (Int 4, Int 3, Int 10).⁹¹

In the future, with these challenges addressed, regenerative medicine could help treat health conditions that present significant burdens on patients and the NHS. Stem cell technology is advancing at a rapid pace, particularly in the United States (US) and Japan, providing crucial foundational research as well as applications in disease areas such as epilepsy and Parkinson’s disease (Int 10). This also may help create opportunities for international partnerships between the UK and other countries advancing this area of medicine. Other foundational technologies in fields such as Artificial Intelligence (AI), gene editing, biomaterial development and microbiotics could also help inform the further development of regenerative medicine in the health system by

helping understand disease causes and how regenerative treatments can be used to help heal or replace damaged tissue.^{92,93} With barriers to research addressed and progression in the technology, regenerative medicine can support patients with pressing conditions, including

long-term diseases that disproportionately impact marginalised communities.

Box 3 highlights examples of the current impact and future potential of regenerative medicine.

Box 3. Regenerative medicine: current impact and future potential



CURRENT IMPACT EXAMPLES

Applications in transplantation to reverse tissue damage, improve patient quality of life and reduce needs for ongoing treatment:

- Applications in the UK are largely confined to trials in areas of trachea transplantation based on stem cell-based tissue-engineered tracheas⁹⁴ and regenerative medicine for bone damage.^{87,88} NHS patients received hip surgery using this method between 2014 and 2020, and as of 2020, none had required further replacement or experienced dislocation or fracture.

Treatment for Sickle Cell Disease:

- The broader field of regenerative medicine and tissue engineering has seen success, including in treating Sickle Cell Disease.^{93,95}
- NICE approved the use of stem cell technology-reliant gene therapy for sickle cell disease in January 2025 for applications in the NHS.⁹⁵



UNTAPPED POTENTIAL FOR NHS AND PATIENT BENEFIT

Applications in conditions disproportionately affecting underserved population groups to target inequalities:

- Thalassaemia is a blood disorder that requires patients to have blood transfusions every 2-4 weeks, creating a high clinical burden and healthcare utilisation amongst affected patients.^{96,97} The disease overwhelmingly impacts population groups, including from South American, Caribbean and Asian/South Asian communities in the UK and can be a source of health inequalities as well as comorbidities.^{96,97}
- New stem cell therapies in the NHS could potentially cure this disease in the future, overcoming these issues.

Expanding research and treatment using stem cells, drawing on advances in the UK and learning from international practices:

- Cellular reprogramming – or turning normal cells (e.g. skin cells) into stem cells for repurposed use in other parts of the body – has the potential to be a platform for wider regenerative medicine and tissue engineering applications. This technology can provide the foundation for other innovative processes, including the development of organoids and bioengineered organs.⁹⁸⁻¹⁰⁰
- Researchers in the US are experimenting with using pluripotent stem cells to treat conditions such as epilepsy,¹⁰¹ diabetes,^{102,103} and Parkinson's disease.¹⁰⁴
- Stem cells are also used to treat multiple sclerosis and in blood transfusions in the UK (Int 10).^{68,105}
- Globally, there are also applications being explored in kidney and cartilage repair and cancer.^{98,100} The potential to offer lifesaving treatment in kidney repair is large, given the number of patients requiring kidney transplants and organ shortages and waiting times. Stem cell technologies also offer significant potential for applications related to transplant rejection.⁹⁸

Moving beyond applications focused on repairing damage to treating the underlying causes of disease⁹³:

- For example, using AI, biomaterials, microbiotics and gene editing to create or regenerate vital organs using organoids, e.g. lab kidneys for later transplants.^{92,93}

Precision care using regenerative medicine:

- On-demand bioprinting would enable living cells and materials to be used to 'print' more precise tissues and organs, customised to the patient, such as bladder or skin, and help deal with organ donor shortages.¹⁰⁶
- There is also potential for using organoids (tissue engineering) to better understand vaccine response and to monitor and treat congenital conditions in fetuses before birth.¹⁰⁷



**Next-generation biologics
(other than gene editing
and synthetic biology and
regenerative medicine/stem
cell applications discussed above)**

Next-generation advanced medicines are a broad category of novel treatments that are made from modified cells or organisms and can be used to help treat diseases earlier and more effectively, including in areas such as cancer, genetic disorders, neurodegenerative diseases, infectious diseases and other key public health challenges such as obesity.

Some examples, as discussed in previous sub-sections, include gene, epigenetic, and CAR-T cell therapies to treat diseases like cancer. Others, as covered in this section, include **GLP-1 agonists** for the treatment of obesity and diabetes; **antibody-drug conjugates** to treat recurrent or metastatic cancer; **monoclonal antibodies** for respiratory diseases; **RNA interference (RNAi) therapies**, novel **Alzheimer's drugs**; **microbiome treatments** to help fight infections and support immunity and **messenger RNA (mRNA) vaccines**.

These types of next-generation biologics illustrate the diversity of advancements in the field and the importance of novel biologic therapies for patients and the NHS, both in terms of current impact and future potential.

Many next-generation biologics are informed by advances in genomics, proteomics and synthetic biology, illustrating the importance of the convergence of research and innovation disciplines in enabling progress.

In addition to genomic medicine and synthetic biology examples discussed in previous sub-sections, other next-generation biologics are currently benefiting the NHS and patients in the UK, although at a limited scale, with high potential for scaling up impact in the future. For example:

- **Novel formulations of GLP-1 agonist drugs** (Wegovy and Ozempic), which mimic the glucagon-like peptide 1 hormone that slows gastric emptying and promotes the release of insulin.¹⁰⁸ These drugs are already helping some patients with weight loss,¹⁰⁸ a major public health concern¹⁰⁹ given that (based on 2022 data) 29% of adults in England were living with obesity, and 64% were considered to be overweight or living with obesity.¹¹⁰ Even so, the ability to scale will depend on addressing affordability challenges and on improved long-term outcomes and impact data from real-world use. Research is also ongoing into other application areas such as depression¹¹¹ and alcohol addiction.¹¹²
- **RNA-based treatment innovations:** For example, **messenger RNA (mRNA) vaccines** gained prominence for their use during the COVID-19 pandemic and their expanded use could open up novel treatment frontiers for currently incurable diseases, reduce pressures on the NHS and inform and support pandemic preparedness.^{113–118} **RNA interference (RNAi) therapies** aim to silence faulty genes and achieve functional cures in areas like Hepatitis B and to reduce inflammation, fibrosis and liver damage.^{119–121} Their growing use in the NHS, for instance, to treat genetic diseases causing organ damage, has been shown to produce improved quality of life for patients and slow disease progression.^{122,123}
- **Innovations in antibody-based treatments:** For example, **Antibody Drug Conjugates (ADCs)** that combine an antibody with a drug are being used in the NHS to treat some types of cancer.^{124,125} Further advances with these types of treatments may expand applications and efficacy in solid tumours with reduced side effects such as toxicity.¹²⁶ **Monoclonal antibodies**

have already been successfully deployed against some respiratory diseases³ and offer new prospects for targeted treatment of other respiratory,^{127,128} and neurodegenerative conditions¹²⁹ with recent advances, including new Alzheimer's drugs. In 2024, dementia was estimated to cost the UK £42bn, projected to rise to £90bn a year by 2040 if the current trend continues.¹³⁰ However, novel drugs will need to prove cost-effective for the NHS.^{131,132,133} While new Alzheimer's drugs could mean that patients with Alzheimer's disease are able to lead independent lives for longer and thus reduce the need for care, they would also require additional health care services for diagnosis, administering the treatment, monitoring and treating potential adverse events.¹³⁴ Future potential exists, but success will also depend on an improved cost-benefit profile and bigger effect size.¹³⁵ T-cell engagers (i.e. **bi-specific antibodies**) could also lead to new applications in oncology.¹³⁶

- **Microbiome-based therapies** (building on advances in our understanding of the

collection of organising living inside our bodies in organs like the gut and helping the body function) also have the potential to help tackle conditions for which there are currently limited options^{137,138} but major impacts on the NHS are likely beyond a ten-year horizon. An exception is faecal microbial transplantation (FMT) for (recurrent) *Clostridium difficile* infection, which is already used in the NHS at a limited scale.^{139,140} FMT involves transferring faecal material from a healthy donor to a patient's gastrointestinal tract to restore the gut microbiome (collection of microbes in the gut).¹⁴⁰ There remains a need to advance the evidence base on cost-effectiveness and to address donor-related, regulatory, access and quality control challenges in order to scale up access across the NHS.

Box 4 highlights some examples of current impact and future potential from next-generation biologics (other than genomic medicine and synthetic biology applications discussed earlier).

Box 4. Other next-generation biologics: GLP-1 agonists, mRNA vaccines and the microbiome-current impact and future potential



CURRENT IMPACT EXAMPLES

Novel biologics for more effective treatment of major public health challenges such as obesity: While GLP-1 agonist drugs have been in use clinically for decades for the treatment of diabetes, recent formulations (e.g. Wegovy and Ozempic)¹⁰⁸ have demonstrated efficacy for the treatment of obesity – a major public health concern.¹⁰⁹ Some NHS patients already benefit from access to GLIP 1s, which can significantly help with weight loss while patients are on treatment.¹⁴¹ However, these drugs are also currently expensive, costing approximately £3,000 per patient annually,¹⁴² and further evidence on long-term effects is yet to accrue.¹⁴³ Semaglutide (Wegovy) is available for weight loss only as part of specialist weight management services. The drug can currently only be prescribed for two years.¹⁴³

Antibody-drug conjugates (ADCs) that combine a monoclonal antibody with a cytotoxic drug for the treatment of cancer. These are already being used in the NHS in areas such as breast cancer, lymphomas and leukaemias.^{124,125}

Drugs for neurodegenerative conditions: Some treatments for Alzheimer's now exist and aim to slow progression but have been assessed by NICE as having limited effectiveness and also come with high costs (e.g. lecanemab and donanemab).¹²⁹

Microbiome-based therapies providing solutions for recurrent gut infections which cannot be cured with antibiotics: Faecal microbiota transplantation is being used to effectively treat recurrent CDI (rCDI), a debilitating infection which is a significant cause of hospital-acquired diarrhoea infections that can be life-threatening for patients, and can occur after antibiotic use.¹⁴⁴



UNTAPPED POTENTIAL FOR NHS AND PATIENT BENEFIT

mRNA vaccines for infectious diseases and cancer could help treat previously incurable diseases, reduce pressure on primary care, save costs on lifetime treatment and help with pandemic preparedness and antimicrobial resistance.

Trials are ongoing for influenza¹¹⁴ cancer,¹¹⁵ HIV/AIDS,¹¹⁶ HSV-1,¹¹⁷ norovirus¹¹⁸ and tuberculosis.¹¹³ mRNA vaccines also have potential for pandemic preparedness and the treatment of antimicrobial resistant bacteria.¹⁴⁵

Bi-specific antibodies (e.g. T-cell engagers) offer significant potential for cancer treatment.

They are showing particular promise for haematological cancers like leukaemia and lymphoma.¹⁴⁶

RNA interference (RNAi) therapies: with curative potential in some areas and therapeutic in others. Applications being explored relate to areas like hepatitis B and liver disease.^{119–121}

Monoclonal antibodies for respiratory and neurological conditions. Applications in COPD¹²⁸ and asthma¹²⁷ offer prospects for targeted treatment for patients, especially those with severe forms of disease. Novel monoclonal antibody-based treatments also offer hope and have prospects for further advances in areas like Alzheimer's disease and other neurological conditions,¹²⁹ although current novel treatments are not recommended by NICE for use in the NHS in light of assessments of current cost-effectiveness.¹⁴⁷

Moreover, the effective use of novel drugs like Lecanemab and Donanemab depends on widespread access to early diagnosis, which remains challenging for the NHS. It would also be important that the new drugs are rolled out in an equitable way.

Novel uses for GLP-1 agonists might help tackle complex public health conditions in combination with non-pharmacological interventions, including holistic care (Int 14).

Research is ongoing into potential additional uses of GLP-1s for treating depression¹¹¹ and alcohol addiction.¹¹²

Novel microbiome therapeutics could deliver patient and NHS benefits for conditions where treatment options are scarce or of limited effectiveness, but this is likely beyond a ten-year time horizon. The gut microbiome has been linked to chronic autoimmune and inflammatory conditions, cardiovascular disease, cancer and psychiatric disorders. Novel treatments (e.g. engineered live biotherapeutic products or microorganisms) show promise for treating cancer as well as rare diseases like phenylketonuria.¹⁴⁸



Novel antimicrobials and alternatives to antibiotics to fight antimicrobial resistance (AMR)

Novel antimicrobials and alternatives to antimicrobials have become a key focus in helping prevent the emergence of antimicrobial resistance (AMR), a serious public health concern and a consideration for the future of treatment. These treatments include **bacteriophages** (also known as phages), **antimicrobial peptides**, **monoclonal antibodies**, and **gene therapies**, all of which have applications in addressing infectious diseases.³

These antimicrobial alternatives can support efforts to curb AMR and its negative impacts.

At present, phage therapies have been used only on a limited number of patients in the UK.¹⁴⁹ However, these therapies are used more extensively abroad. Bacteriophages are already routinely used in countries such as Poland and Georgia¹⁵⁰ and can be used as experimental treatments in emergency cases in the US and the European Union (EU).¹⁵¹ Monoclonal antibodies have been used to successfully treat COVID-19 patients in the UK,^{152–154} and have additional applications for diseases such as RSV abroad.³

Increased policy focus on measures to combat AMR in the UK has supported the progression of novel treatments within the UK. Bacteriophages are receiving increased attention in the UK, including the January 2024 House of Commons report into bacteriophage potential¹⁵⁵ and the DHSC response in May 2024.¹⁵⁶ Moreover, the UK established the Phage Innovation Network in February 2023 to generate and share knowledge on phage therapy¹⁵⁷ and the UK Phage Therapy initiative in 2022 to serve as national clinical service.¹⁵⁸ These programmes have been particularly useful for generating evidence on phage therapy – an ongoing challenge, given the difficulty of measuring impacts

for such a personalised treatment where an individual's unique microbiome will have a key effect on the effectiveness of specific phage therapies.¹⁵¹ Work to develop phage therapy exists in a wider context of policy to address AMR – efforts include the 2019–2024 and 2024–2029 AMR national action plans (NAPs), which emphasised the importance of optimal use of antimicrobials, including through encouraging improved surveillance of AMR and piloting new subscription-model payments to reduce overprescribing of antimicrobials.^{159,160} Increasing innovation in response to the real threats AMR poses is a key focus of the latest AMR NAP, including the potential development of phages as alternatives to antimicrobials.¹⁶⁰

Alternatives to antibiotics offer future prospects for treating and preventing drug-resistant infections, saving lives and preventing unnecessary downstream health service utilisation.

In the future, advances in phage therapy, antimicrobial peptides, gene therapies and monoclonal antibodies could reduce the threat that AMR poses to the NHS and wider society. In this vision, patients would receive more personalised antimicrobial therapies as part of routine NHS practice, specifically through more use of bacteriophages. Monoclonal antibodies could also be used more in routine care, particularly in treating viral pathogens such as RSV, Ebola, Zika and SARS-CoV-2). Building on the benefits of monoclonal antibodies, including a targeted approach to infection with lower toxicity, could save lives and prevent unnecessary hospitalisations. Even so, various scientific and technological challenges must be overcome to address this from a scientific, regulatory and governance perspective. Moreover, realising the potential of these novel innovations will require infrastructure for more personalised medicine.

Box 5 highlights some examples of the current impact and future potential of novel antimicrobials and alternatives to antibiotics to fight AMR.

Box 5. Novel antimicrobials and alternatives to antibiotics to fight AMR: current impact and future potential



CURRENT IMPACT EXAMPLES

Phages that help fight drug-resistant infections, save lives and reduce the need for repeated treatment over time:

- Phages reduce the need for multiple treatments with antimicrobials and thus help mitigate the AMR risks associated with their use. Additionally, phages have low toxicity, with few and generally mild adverse side effects.¹⁴⁹
- Phage therapy use in the UK is at present limited to a very small number of patients (12 as of 2023)¹⁴⁹ and is currently relatively costly.³ Access is tied to the ability of NHS Trusts to procure and provide unlicensed medicine and is dependent on clinical knowledge about how to handle phages.¹⁶¹
- Even so, phages can also be used to help prevent infections (e.g. in wound dressings, catheters and implants), improving patient outcomes and experiences and saving the need for further health resource utilisation.
- More generally, phages can be life-saving for patients with different types of infections where traditional antibiotics have not worked,¹⁴⁹ including sepsis, meningitis, pneumonia, osteomyelitis, septic arthritis, pyelonephritis, chronic nonhealing wounds, and periodontitis.¹⁵¹

Monoclonal antibodies have valuable applications in infectious disease treatment:

- Monoclonal antibodies have been used to successfully treat COVID-19 patients in the UK and have additional applications for diseases such as RSV abroad.³ Their use, particularly in treating COVID-19, has been shown to be effective in reducing disease severity and morbidity.^{152–154}



UNTAPPED POTENTIAL FOR NHS AND PATIENT BENEFIT

Scaling of phage therapy:

In the future, phage therapy may be used across primary, secondary and community-care settings.¹⁴⁹ It will be recognised as a crucial part of the fight against AMR, and appropriate infrastructure, including Good Manufacturing Practice (GMP), will exist to support solution development and rollout.¹⁴⁹ To achieve this, infrastructure will be required to scale innovations across the NHS, and staff will need support to implement novel therapies.

Personalised and engineered phages:

In addition to existing 'phage cocktails' (i.e. combinations of phages), the future of treatment with phages could include personalised, unlicensed treatments. This will likely consist of selecting particular phages from a phage bank that are effective against individual patient infections or engineering phages with specific capacities (e.g. faster replication, better specificity against particular bacteria). This would result in a future with more highly personalised medicine.^{151,162} Technical advances may also allow for genomically engineered phages that only target resistant bacteria.¹⁵¹

More effective novel antimicrobials and antibiotic alternatives:

Many bacteria produce biofilm that is hard to penetrate, and that can lead to reduced monoclonal antibody efficiency at present. Future treatments will overcome this challenge, improving the effectiveness of novel antimicrobials and alternatives.

Leveraging technology to support AMR measures:

- AI will be used to identify novel antimicrobial compounds (e.g. antimicrobial peptides),³ informing novel drug discovery.

Creating novel drug delivery systems

- Phages can be used to create advanced drug delivery systems alongside nano-particles to enhance personalised treatment for infectious diseases such as tuberculosis.¹⁶³

Monoclonal antibodies for bacterial infections and AMR:

The use of monoclonal antibodies to treat bacterial infections (in addition to viral) could be expanded, for example, to treat diseases such as pneumonia and recurrent *C. difficile* infection.³



Chronotherapeutics

Not all novel treatment paradigms are about developing novel

products and technologies. There is also significant potential for greater effectiveness from existing treatment approaches based on scientific advances.

One such approach is **chronotherapeutics**, which relies on adjusting the timing of therapy administration to the body's natural biological and circadian rhythms – which influence the metabolism, hormone release and sleep/wake cycles – to improve treatment effectiveness. There are three types of chronotherapy: (1) medication chronotherapy, which synchronises drug treatment with the body's circadian rhythm (2) light chronotherapy, which focuses on the influence of light and timing on the circadian system; and (3) food chronotherapy, which looks at the influences of feeding patterns and the gut microbiome on the circadian rhythm.¹⁶⁴ Research in this area ties close links between circadian rhythm and diverse treatment areas, including cardiovascular well-being and treatment.¹⁶⁴ Rather than proposing a radical change, chronotherapy represents an incremental innovation that builds on current treatment pathways and does not require a complete overhaul of existing systems.¹⁶⁵ It can nonetheless save substantial NHS resources and enhance patient outcomes, using fewer treatments more effectively to achieve the desired effect.¹⁶⁶

Chronotherapeutics can increase treatment effectiveness and reduce medication side effects at little cost to the health system, improving patient outcomes and economic outputs (see Box 6). Some treatment approaches already consider the timing of treatment administration, e.g. the treatment of chronic conditions like cardiovascular diseases, asthma and certain cancers.¹⁶⁷ This has

been proven to produce key positive impacts, including higher survival rates for patients with colorectal cancer¹⁶⁸ and a reduction in major cardiovascular events in patients taking blood pressure medications.^{169–172} Aligning drug administration with biological rhythms may also reduce the incidence of adverse drug reactions, as the body may be better equipped to handle the drug at certain times. In addition to their direct benefits on patients, chronotherapeutic approaches also have secondary benefits, including reducing the number of drugs wasted due to ineffectiveness or improper timing and improving the economic activity of patients on medication for chronic diseases.

Chronotherapy has gained increasing attention in recent years for its potential to improve treatment outcomes and save health system resources across various conditions.

Research in the UK is exploring its applications in diverse areas. However, there remain challenges to address (Int 12). While there has been progress in research in this area, particularly in Northern European contexts (Int 12), chronotherapeutics is not a regular part of healthcare, and only 0.1% of ongoing clinical trials include considerations of the time of day in their analyses.¹⁷³

In the future, chronotherapeutics can form a key part of personalised medicine, improving patient outcomes at a wide scale and achieving widespread health system impact.

Research on chronotherapeutic approaches to care is ongoing and has yet to gain substantial traction in the UK health system beyond isolated applications (e.g. for cardiovascular medication timing). Future research may help expand applications of chronotherapeutics, for instance, for applications in chemotherapy timings and the treatment of bipolar disorder.^{174–176}

Box 6. Chronotherapeutics – current impact and future potential



CURRENT IMPACT EXAMPLES

Increasing effectiveness and reducing side effects through appropriate timing of treatment administration.

- Some treatment approaches already consider the timing of treatment administration, e.g. the treatment of chronic conditions like asthma, cardiovascular diseases, and certain cancers.¹⁶⁷



UNTAPPED POTENTIAL FOR NHS AND PATIENT BENEFIT

Novel chronotherapeutic applications with the potential to improve the effectiveness of treatments in a range of conditions, reduce the number of drugs used and reduce costs of care for the NHS:

- Research and trials are currently taking place in a range of areas, including cancer (minimising side effects of chemotherapy^{175,176}) and bipolar disorder.¹⁷⁴
- Further research is needed to understand how personalisation of treatment timing is affected by biological traits and variables such as age, sex or chronotype (types of circadian rhythm).¹⁷⁷

Innovations in wearable technology and digital health tools could facilitate the monitoring of patients' biological rhythms:

Technological advances to precisely understand patients' specific rhythms could provide foundational support for chronotherapeutics, allowing for more precise timing of treatment by individual patients.

Novel health technology paradigms



Technology, digital and data-enabled therapeutic innovation in mental health

Common mental disorders, such as anxiety or depression, are estimated to be experienced by 1 in 6 adults in England.¹⁷⁸ Despite this, mental health is a neglected area compared to other health conditions, with research and innovation chronically underfunded compared to the burden of mental health disease.^{179–181} This makes the current rapid emergence of tech-enabled treatment (e.g. online therapies) particularly exciting. We are also seeing some developments with pharmacological interventions in areas where there has been little or no progress for a long time (e.g. schizophrenia^{182,183}).

Technology-enabled care for mental health is already benefiting patients and the NHS (see Box 7). Services such as remotely delivered NHS Talking Therapies and other online cognitive behaviour therapies are currently available for NHS patients with conditions such as anxiety, depression and insomnia. AVATAR therapy can also be offered in the NHS (while more evidence is generated) as a treatment option for people who hear voices.¹⁸⁴ Patients engaging with Talking Therapies and AVATAR therapy show reductions in symptoms and increased quality of life.^{185–190} There is also emerging evidence of potentially favourable cost-effectiveness.^{191–194} Digitally enabled mental health treatments might also

allow clinicians to see more patients and thus use NHS resources more efficiently.^{190,194–198}

Digital mental health interventions could increase access to mental health treatment overall^{192,194,196} and offer a treatment option faster for patients who might otherwise face a waiting time of several weeks.¹⁷⁸

Within the next ten years, technology for mental health care could improve access to innovative therapies, increase care efficiency and make the best use of data to improve care further.

Digital and remote therapies can help overcome logistical and geographical barriers to providing care.^{199–204} Tech-enabled mental health treatments can also help mitigate stigma and thus improve uptake by patients.²⁰⁵ Using natural language processing and AI-powered chatbots could help speed up the review of complex case files and improve care efficiency.^{205,206} Virtual conversational agents for treating people who hear voices could be further enhanced by immersive virtual reality.¹⁸⁹ Digitally delivered treatments and wearable technology also enable the collection of diverse and rich data, which could help improve the understanding of mental health conditions and treatment impacts.^{201,203,205,207} The potential of data for mental health improvement is already demonstrated by large psychiatric databases accessible to the NHS, such as those being developed by Akkrivia.²⁰⁸

Box 7 highlights some examples of the current impact and future potential of technology, digital and data-driven innovation in mental health.

Box 7. Technology, digital and data-enabled innovation in mental health



CURRENT IMPACT EXAMPLES

Online talking therapies and other digital mental health treatments offer an alternative, effective care option and can improve access to healthcare for people with mental health conditions:

- NHS talking therapies include online and app-based programmes that contain material based on cognitive behavioural therapy and are supported by trained psychological well-being practitioners.^{195,209,210}
- Examples of tech-enabled care products for anxiety, depression, insomnia and other mental health conditions include Sleepio, SlowMo, CareLoop, Space from Depression, Wysa, Iona Mind, Space from Anxiety, iCT-PTSD and iCT-SAD.
- AVATAR therapy for people who hear voices has been found to significantly reduce symptom severity and frequency in research trials compared to treatment as usual.^{188,189,211}

Digitally delivered mental health services could provide cost-effective care:

- There is emerging evidence that digitally enabled mental health treatments can be a cost-effective option for conditions including depression, insomnia (Sleepio¹⁹³), and anxiety disorders.¹⁹⁴
- Digitally enabled mental health treatments might also enable more efficient use of clinician time to be able to see more patients.¹⁹⁶



UNTAPPED POTENTIAL FOR NHS AND PATIENT BENEFIT

Scaling access to mental health therapies:

- Whilst the therapeutic relationship is important in the treatment of many mental health conditions (e.g. anxiety and depression), the ability to engage with a chatbot that is not influenced by social stigma may increase access to mental health support for those who are particularly concerned about stigma.²⁰⁵ Digital and remote therapies can also help overcome logistical and geographical barriers to providing care.^{199–204}

Using AI to free up capacity of mental health staff:

- Using AI may help clinicians to increase patient-facing time and work more efficiently with lengthy and complex patient notes by summarising.²⁰⁵

Improving understanding of mental health conditions and about effective treatments:

- Potential for collection of more and different types of data through digital treatments to enhance understanding of mental health conditions and treatment impacts. For example, Akrivia is creating a large database of psychiatric data from NHS Mental Health Trusts that are linkable across settings.²⁰⁸ Another example, mindLAMP, is a smartphone app that collects data using smartphone sensors (e.g. geolocation, movement, screen time, notifications), which may help to predict potential relapses in schizophrenia and thus enable healthcare professionals to intervene with treatment at an earlier point.²¹²

Novel pharmacological interventions for neglected mental health conditions:

- In addition to health tech, there is potential for small molecule drug combinations, such as Cobenfy, to improve patient outcomes and quality of life for patients with schizophrenia – an area where there has been little progress to improve treatment for decades.^{182,183}



Functional restoration and brain-computer interface (BCI)

Functional restoration is an innovative field that aims to restore functions in individuals with neurological and neuromuscular disorders. By bridging the gap between the brain and external devices, Brain-Computer Interface (BCI) technologies enable individuals to regain control over their environment and their own bodies. BCIs can be invasive, allowing for more accurate recordings or stimulation, and non-invasive.²¹³ Non-invasive BCI can

use electroencephalography (EEG), which is currently used in research and some clinical applications to aid communication and mobility.^{214,215} Related to BCIs, neuromodulation encompasses techniques that target activity in the nervous systems, either electrically or chemically, usually to aid in managing pain, mobility impairments, neurological disorders and epilepsy.²¹⁶ Deep Brain Stimulation (DBS), an invasive form of neurostimulation, involves implanting electrodes in specific brain regions to treat disorders like Parkinson's disease and epilepsy.²¹⁷ These techniques have unique

applications and challenges, with ongoing research expanding their potential to transform treatment pathways.

The current impact of functional restoration and brain-computer interface technologies is very limited in the NHS. However, it can have a significant impact on the lives of patients who can access the advances in functional restoration therapies. Adoption is limited to very few patients; despite DBS being used to treat Parkinson's disease for several decades now, it is still applied mostly as a last-resource treatment (Int 9). While only a relatively small number of patients can access functional restoration technologies, they can make a profound difference for these patients. Some examples include using cochlear implants to restore hearing to deaf patients²¹⁸, Deep Brain Stimulation (DBS) for patients with Parkinson's disease²¹⁹ and transcranial magnetic stimulation to treat depression.^{220,221} Other applications can be accessed via research studies, such as DBP for obsessive-compulsive disorders²²² or epilepsy.^{223,224}

Early-stage research shows significant promise for BCI and neuromodulation therapies to restore the functioning of severely impaired patients, and it could be relevant for a wide range of conditions.

BCI could enable patients with locked-in syndrome²²⁵ or quadriplegia^{226–228} to communicate and control external devices. They could also be extended to a broader range of conditions, especially those affecting the ageing population²²⁹: retinal degeneration,²³⁰ substance use disorders,²³¹ neuropathic pain,²²⁹ immune function²³² and others. Less invasive neuromodulation

technologies would decrease their risk and potential cost if economies of scale can be realised and expand their acceptability for a wider range of patients. The convergence of technologies and using AI could make neuromodulatory therapies more personalised and effective.²²⁹ Further development of BCI and neuromodulation will, in part, depend on a deeper understanding of nervous system functioning mechanisms,^{231,233,234} which could also allow more precise targeting,²³¹ improve tolerability and efficacy.²³⁵ These techniques have unique applications and some challenges to overcome (such as those related to clinical performance and regulation), with ongoing research expanding their potential to transform treatment pathways.

The ten-year potential of BCI and functional restoration is difficult to estimate: potentially large but uncertain, dependent on progress in research and implementation. However, the burden of neurological disorders is large and current treatments are limited and often focused on slowing deterioration rather than cure or functional restoration (Int 9). In the longer term, BCI and related therapies offer the potential for curative treatment, better patient outcomes and autonomy,²³¹ less long-term impact on the NHS (e.g. reduced hospitalisations and physiotherapy rehabilitation) and social care systems, as well as enabling more patients to be well enough to have a greater contribution to the economy (Int 9).

Box 8 highlights some examples of the current impact and future potential of neuromodulation and BCI technologies.

Box 8. Functional restoration – current impact and future potential



CURRENT IMPACT EXAMPLES

Neuromodulation therapies are used clinically in the NHS for a subset of patients with some neurological and psychiatric conditions:

- Neuromodulation is used within some NHS trusts²³⁶ as part of usual clinical practice.
- Uses include cochlear implants,²³⁰ deep brain stimulation for Parkinson's,²¹⁹ depression,^{221,237–241} pain,^{242–244} spasticity^{242,243} and pelvic floor instability.²⁴³
- For example, Northamptonshire Healthcare NHS Foundation Trust (NHFT) is offering an innovative treatment for depression using the 'Flow' headset,²²⁰ which delivers transcranial direct current stimulation (tDCS) at home, providing an alternative to anti-depressant drugs without their side effects. This treatment, supported by a comprehensive app for monitoring and lifestyle training, has shown significant improvements in depression severity, activity functioning, and quality of life. It is well-received by patients seeking non-medication options and suggests possible future wider impact.

Clinical use of BCI in the UK is currently only within research trials:

- BCI interventions are trialled in the NHS as part of research studies.^{245,246}



UNTAPPED POTENTIAL FOR NHS AND PATIENT BENEFIT

Potential for more people to benefit from improved physical and communication functions through functional restoration therapies:

- Functional restoration technologies may help immobile patients control prosthetic limbs and wheelchairs, restoring some of their autonomy,^{247–250} or enable patients to communicate^{225–228} through linking brain signals with external digital devices.
- Neuromodulation could expand to modulating immunity, with wide implications for auto-immune and infectious disease treatment.²³²
- Technology could automatically adjust stimulation based on a patient's brain chemistry in a closed-loop system.^{231,232,235,251} This could mean faster adjustment of therapy and fewer check-up appointments.



Robotic surgery

Robotic surgery (or robot-assisted surgery) is an established technology with a relatively high degree of adoption within the UK. It is a relatively mature technology (Int 5), and the UK is recognised as one of the most innovative countries in the field.²⁵² Initially (and still) used primarily for prostate-related procedures in urology,²⁵³ the spread of use across specialities is increasing. NICE is currently developing two early value assessments (EVAs) for robot-assisted surgery: for orthopaedic procedures²⁵⁴ and soft-tissue procedures.²⁵⁵

Robotic surgery has demonstrated the potential to improve patient outcomes and increase efficiency, although further evidence is needed to inform decisions about wider-scale use. Robotic surgery can lead to less invasive surgical procedures, with shorter hospital stays, faster and less painful surgery.^{256,257} NHS hospitals adopting robotic surgery deliver a higher number of urological interventions.²⁵⁸ However, after a hospital adopts a robotic surgery system, it may take time for benefits to reach full potential: productivity benefits of robotic surgery for

prostate cancer have been shown to increase over time,²⁵⁸ and require enabling adoption contexts, including integration into wider clinical workflows. In addition, evidence still needs to be generated to better understand the learning curve for surgeons, resource use for set-up, robotic system costs and effects on patient and NHS outcomes.^{254,255}

Gains within ten years are likely to stem from further improvements in the technology, improving cost-effectiveness and broadening the scope of application to a wider range of surgical areas. Robotic surgery is likely to benefit from advancements enabled by AI, as improvements could be implemented quickly. The hardware is also likely to improve, as well as its ability to incorporate sensing and feedback²⁵² and provide opportunities for surgeons to learn²⁵⁹ (Int 5). The cost-effectiveness of robotic surgery technologies hinges on the long-term benefits for patients (e.g. saving QALYs), efficiency of provision (e.g. improved productivity, reduced patient stay and follow-up costs) and implementation costs (e.g. cost of the robot).

Box 9 highlights some examples of the current impact and future potential of robotic surgery.

Box 9. Robotic surgery – current impact and future potential



CURRENT IMPACT EXAMPLES

Robotic surgery for delivering more precise operations for patients in some surgical areas:

- Robotic surgery is mostly used for prostate-related procedures, followed by pelvic lymph node operations.²⁵³
- From 2016 to 2022, the number of robot-assisted surgeries in the UK increased more than four-fold, from 11,000 to 49,000.²⁵³



UNTAPPED POTENTIAL FOR NHS AND PATIENT BENEFIT

Improving cost-effectiveness, broadening the scope of application to more diverse surgical areas and advancing technology performance and precision:

- Productivity gains and cost-effectiveness will likely improve as robotic surgery becomes more integrated and embedded into clinical workflows (Int 5).
- The NHS is likely to see increased adoption of robotic surgery, such as for orthopaedic²⁵⁴ and soft-tissue procedures.²⁵⁵
- The technology may further improve by incorporating AI and other technologies such as tactile sensing, haptic feedback and eye-tracking technology.²⁵²
- Robotic systems might also expand to percutaneous (inter-vascular) robotic technology and self-propelling robotic colonoscopes for examination.²⁵²
- Robotic microsurgery is also likely to expand, as it offers advanced precision for complex procedures, minimising tissue damage.²⁶⁰



Nanobots

Nanobots (or nanorobots) are miniscule devices engineered at the molecular scale, capable of executing precise tasks at the cellular and molecular level. They have the potential to enable targeted drug delivery, enhancing disease prevention and improving therapeutic techniques (Box 10).²⁶¹ Nanobots could contribute to more controlled and active drug delivery using chemical, light, magnetic or temperature stimuli (Int 6). The field is still emerging, with various scientific and technological challenges to overcome (e.g. the properties of nanomaterials, navigating the body's environment and controlling nanorobots in the body).²⁶²

In the future, nanobots have potential

widespread application. Examples include managing bleeds in the brain caused by aneurysms,²⁶³ targeted drug delivery directly to cancer cells to improve effectiveness and reduce side effects,^{262,264} promoting faster and more efficient tissue growth and healing,^{265,266} reducing plaques responsible for heart attacks in cardiovascular disease,²⁶⁷ and drug delivery to infection sites to tackle antimicrobial resistance.²⁶⁸ Given the current experimental stage, impact at scale is likely beyond a ten-year horizon.

Box 10 highlights some examples of the current impact and future potential of nanobot technologies.

Box 10. Nanobots – current impact and future potential



CURRENT IMPACT EXAMPLES

Early-stage R&D efforts showing promise in targeted drug delivery through nanobots:

- Nanobot treatment technology is still being developed. The current impact is through early-stage research and is not widespread.



UNTAPPED POTENTIAL FOR NHS AND PATIENT BENEFIT

Nanobots have potential widespread application to deliver more precise and targeted treatments to patients:

- Unlike traditional chemotherapy, which can affect both healthy and cancerous cells, nanorobot-assisted targeted therapies for cancer treatment aim to interact specifically with the unique markers found on cancer cells, thereby reducing harmful side effects.²⁶⁹
- For tissue repair and regeneration, nanobots could accelerate the healing process by delivering targeted substances that promote faster and more efficient tissue growth.^{265,266}
- For cardiovascular disease, nanobots could target and reduce the plaques responsible for heart attacks, potentially offering a new treatment for atherosclerosis, a major cause of heart attacks.²⁶⁷ Another potential application is managing bleeds in the brain caused by aneurysms in a precise, low-risk way.²⁶³
- For infections, nanorobots can deliver drugs directly to an infection site with high precision, using their ability to move and apply force to penetrate biofilms (the protective layers formed by bacteria), offering an alternative to traditional antibiotic treatments and helping to address antimicrobial resistance.²⁶⁸



Smart pills

Smart pills are drug-device combination pills that are

ingested, contain electronic or mechanical elements, and can have diagnostic and therapeutic applications in the gastrointestinal (GI) tract.²⁷⁰ **Diagnostic** smart pills, such as capsule endoscopy, are already used in the UK.^{271–273} The capabilities of diagnostic smart pills are expanding to sensing pressure, temperature, pH and biomarkers.²⁷⁰ Another application of smart pills is **monitoring drug adherence**: such pills are equipped with a sensor to track if they have been ingested and paired with an external device (e.g. a patch or pendant). The first drug adherence monitoring smart pills reached the market around a decade ago but lost prominence somewhat due to setbacks of the early licenced products.²⁷⁴ **Therapeutic smart pills** are currently actively researched and could deliver drugs locally in the GI tract, inject drugs for systematic treatment or deliver

nonpharmaceutical interventions.²⁷⁰ The most advanced products are in early-stage clinical trials.^{275,276}

Smart pills have a large potential to improve treatment for GI diseases and offer an alternative way to administer systemic treatment. For patients with inflammatory bowel disease, smart pills could offer a much more localised and targeted treatment, reduce side effects and improve outcomes.²⁷⁷ Smart pills capable of injecting medicines using micro-needles or alternative technologies through the GI wall could replace drug injections – offering the advantage of being completely painless.^{278,279} Further applications are ingestible expanding pills (similar to intragastric balloons) for obesity treatment, vibration for constipation treatment, and electrical stimulation to modulate GI tract motility.²⁷⁰

While smart pills have the potential to change the outcomes of specific patients and offer a novel alternative for delivering drugs such

as biologicals, the impact likely lies beyond a ten-year horizon. The most advanced studies are in early-stage clinical trials.²⁷⁸ The technical challenge of fitting the required components into a pill that could be safely

swallowed^{270,280} and of safe and sustainable manufacturing^{277,280} remain (Int 1).

Box 11 highlights some examples of the current impact and future potential of smart pill technology applications in treatment.

Box 11. Smart pills – current impact and future potential



CURRENT IMPACT EXAMPLES

Treatment applications are not used in the NHS. Diagnostic applications are limited in practical application, although some examples are enabling less invasive diagnosis, e.g. colon capsule endoscopy for cancer diagnosis²⁷³ and using a capsule camera swallowed by the patient and diagnostic pills to capture 'events' such as meals, bowel movement, bloating, nausea or abdominal pain. Treatment applications could learn from health systems adoption strategies used in the diagnostic space.

Smart pills for treatment are currently not used in clinical practice:

- The most advanced products are in early-stage clinical trials.^{275,276}

Smart pills have been used for drug adherence monitoring, but the first applications have not become widely used:

- A smart pill called Abilify Mycite developed by Proteus Digital Health and Otsuka Pharmaceuticals was approved to treat patients with schizophrenia and track the patient's adherence to the treatment in the US in 2017, with a factory planned to be built in the

UK.²⁸¹ However, the companies struggled to offer competitive pricing given its incremental improvement compared to standard practice²⁷⁴ and was not approved by the European Medicines Agency (EMA).²⁸²

Diagnostic smart pills are established as an alternative to endoscopy, with further applications also used clinically:

- In the UK, NICE issued guidance to support the use of capsule endoscopy in 2004.²⁷¹
- Other products include a motility testing smart pill that measures pressure, pH, transit time and temperature and can provide diagnostic information,²⁸³ which has also been trialled in the UK.²⁷²



UNTAPPED POTENTIAL FOR NHS AND PATIENT BENEFIT

Smart pills could deliver localized site-specific treatment to the GI:

- Targeted delivery offers the potential of avoiding systemic administration when not necessary, which could reduce side effects.²⁷⁰
- Drug-device combinations could also gather information through sensors during the drug administration.²⁷⁰
- Site-specific release of drugs might be particularly impactful for patients with inflammatory bowel diseases (IBD), as it could reduce systemic side effects and improve adherence, especially when new therapeutics are used.²⁷⁷

Smart pills could offer oral administration as an alternative to drugs that currently must be injected or have poor absorption from the GI tract:

- Drugs' bio-availability could be increased by using smart pills, which can help to overcome enzymatic degradation, adverse pH conditions, microbiota, mucus barriers and difficulties in crossing the epithelial barrier.²⁷⁰
- Smart pills could replace injections and increase adherence (e.g., daily insulin injections can lead some patients to skip doses). While many technologies are being developed, few are yet at the clinical trial stage.²⁷⁸
- Smart pills could deliver drugs such as GLP-1 agonists and RNA molecules through the GI tract wall pain-free, including an option without any needles, reducing the risk of tissue damage.²⁸⁴ However, testing in humans is still in the future.

Non-pharmaceutical treatment smart pills might also have potential applications:

- Potential treatment areas include ingestible expanding pills (similar to intragastric balloons) for obesity treatment, vibration for constipation treatment, and electrical stimulation to modulate GI motility.²⁷⁰

Chapter 3. Discussion: the time horizon for the impact of novel treatment paradigms and a vision for the future

The timeframe for impact

The impact of novel treatment approaches will vary over a ten-year horizon. The reasons for this include differences in the current state of scientific and technological development, the scope and scale of application to diverse health conditions and populations and the readiness of the health and innovation system to support the translation of research and innovation into NHS practice. In reflecting on the insights gained on current impact and future potential of novel treatment paradigms to support NHS transformation, there is an opportunity to accelerate impact on patients and the NHS by focusing short and medium-term efforts on the testing, adaptation/refinement and adoption of more mature novel treatment paradigms. At the same time, emerging but high-potential areas of science and technology can progress with R&D support.

Drawing on insights from the literature and stakeholder consultations as part of this project, Tables 3 and 4 summarise the relative maturity of diverse biological and health technology paradigms and time horizons for impact.

They show that a substantial opportunity exists to scale existing impacts from some treatment modalities, achieve new impacts and expand the scope of application areas in a ten-year horizon. The tables also highlight more nascent developments with high transformative potential that would benefit from R&D support to ensure that the UK population is not left behind in the long term in terms of contributing

to developing novel solutions and ensuring access to them.

Some novel treatment types are at more advanced stages of scientific and technological development than others, resulting in variation in potential scale and likelihood of impact on the NHS in a ten-year horizon. Building on scientific advances, patients are already benefiting from more personalised and precise therapies for cancer, novel therapies for obesity, or digitally enabled talking therapies to help solve major mental health challenges like anxiety and depression. Other novel treatment paradigms are much more nascent, such as chronotherapeutics, smart pills for targeted drug delivery and adherence monitoring and nanobots (minuscule robots) for more precise drug delivery.

The different scope of application of diverse novel treatments in terms of health conditions and populations they apply to means that the scale of impact in a ten-year time horizon will also be diverse and difficult to predict robustly. For example, techniques that can help people regain abilities they have lost have significant potential applications in neurology. Other types of treatments (e.g. based on altering and repairing faulty genes or using proteins made in the lab to boost the immune system to destroy and fight off diseases) could have applications across a wider range of conditions and populations, in chronic non-communicable, rare and infectious diseases.

Investment into the support systems needed to accelerate the development and adoption of diverse treatment paradigms also varies and

will influence the likelihood and scale of impact in a ten-year horizon (see Tables 3 and 4). For

example, the UK has already made significant investments in the workforce, physical and data infrastructure in areas like genomic medicine and synthetic biology, and to some extent in regenerative medicine. That said, further strengthening of support systems is needed in these areas to realise their full potential.

In relative terms, there has been far less investment in bolstering capacity and advancing the potential in areas such as functional restoration, smart pills and the microbiome.

Table 3. The horizon for impact: where we are and where we can be with novel biological paradigms for the NHS

Novel treatments	What are they	Existing applications	Potential in a 5–10 year time horizon	Longer-term impacts (>10 years)
 Genomics and multi-omics supporting personalised medicine	Genomic medicine uses information about a person's genes (DNA) to diagnose, prevent or treat diseases like cancers and rare diseases. Genomic data can be coupled with other types of information to develop more personalised, precise and effective treatments. Pharmacogenomics helps understand how a person's genes affect their response to medications.	Targeted cancer therapies and early access through trials (e.g. PARP inhibitors,^{21,22,285} glioblastoma³⁷; pharmacogenomics (e.g. cancer,^{24,286} HIV)^{28,287}; CRISPR and gene therapy (e.g. sickle cell and β thalassaemia^{23,288}).	Scaling existing gene therapy applications, novel epigenetic therapies (cancer, heart disease, dementia³⁴), gene therapies (e.g. amyloidosis,^{44,45} muscular dystrophy⁴⁶). Expansion of epigenetics-based personalised medicine from cancer and rare diseases to other disease areas (e.g. cardiovascular, liver, respiratory).²⁸⁹	While there is likely to be innovation in proteomic therapies and treatments over the next ten years, the benefits are likely to be realised later. Innovations in proteomics could change how drugs are developed and enable widespread treatment of disease before diagnosis (Int 2).
 Synthetic and engineering biology supporting personalised medicine	Synthetic biology uses engineering methods to modify biological organisms to give them new functions or create new types of biological compounds to develop treatments that work better for patients, as well as to improve their survival and quality of life. It creates prospects to treat diseases that are currently very hard to treat, like cancers and genetic disorders and to develop treatments quicker or more efficiently.	CAR-T cell therapies (lymphoma,^{290,291} leukaemia²⁹²), mRNA vaccines for SARS-CoV-2,⁵³ liposome nanomaterials for hereditary transthyretin amyloidosis,¹²³ oncolytic viruses for melanoma.²⁹³	CAR-T cell therapies for solid tumours,²⁹⁴ tumour-infiltrating lymphocyte and synthetic biology (mRNA) immunotherapies for cancer,²⁹⁵ expanded use of oncolytic viruses.⁶⁵	Potential areas for progress in these areas over the next ten years are in immune reset stem cells (e.g. for autoimmune diseases)⁶⁸ and programmable cells.⁶⁶

Novel treatments	What are they	Existing applications	Potential in a 5–10 year time horizon	Longer-term impacts (>10 years)
 Regenerative medicine	Regenerative medicine creates prospects for using techniques like stem cells, engineering of tissue and gene therapies (which use tools like CRISPR to edit, alter or replace faulty genes) to repair, replace or restore damaged tissue (e.g. hip fracture), to stop the body rejecting transplanted organs to enable more success in transplant procedures.	Regenerative medicine (trachea replacement,⁹⁴ hip fractures^{87,88} and sickle cell disease⁹⁸).	Regenerative medicine in cartilage repair; simple bioengineered organs and on-demand bioprinting; stem cell treatments for transplant rejection.⁹⁸ Early applications of regenerative medicine to address chronic conditions such as Type 1 Diabetes.¹⁰²	In a longer time horizon, there is potential for regenerative medicine to address and repair the causes of disease and to treat long-term diseases such as epilepsy¹⁰¹ and Parkinson's disease.¹⁰⁴
 Next-generation biologics (other than those covered above)	Next-generation advanced medicines made from cells or modified organisms can help treat diseases more effectively. They include therapies to fix genes (gene therapies) or switch them on and off (i.e. epigenetic therapies) to treat diseases like cancer, new treatments that restore a healthy gut microbiome (e.g. helpful bacteria in the gut) to help fight infections and keep the immune system strong, or novel formulations of medicines that control blood sugar levels to help treat major public health challenges like obesity (e.g. GLP-1 agonists).	GLP-1 agonists (diabetes²⁹⁶ and obesity²⁹⁷), faecal microbiota transplantation (Clostridioides difficile),²⁹⁸ antibody-drug conjugates (cancer)^{124,125}; some treatments for Alzheimer's (but limited effectiveness and high cost).^{129,147}	Scaling GLP-1 agonists use in obesity, and exploring the potential in treating depression²⁹⁹ and alcoholism and substance use³⁰⁰ Bi-specific antibodies (cancer),¹³⁶ RNA therapy (e.g. hepatitis B301), monoclonal antibodies (COPD¹²⁸ and asthma¹²⁷).	After ten years, there is potential for novel microbiome applications for chronic autoimmune and inflammatory conditions, cardiovascular disease, cancer and psychiatric disorders.¹⁴⁸ Another possible growth area is in mRNA vaccines for AMR.¹⁴⁵

Novel treatments	What are they	Existing applications	Potential in a 5–10 year time horizon	Longer-term impacts (>10 years)
 Novel antimicrobials and alternatives to antibiotics	Novel antimicrobials and alternatives to antibiotics are giving us opportunities to find new ways to fight infections and tackle antimicrobial resistance, using methods like very small viruses (called bacteriophages) to kill bacteria or improve our body's immune response.	Phage therapy for bacterial infections and monoclonal antibodies against viral infections.^{158,302}	Scaling of phage therapy,^{156,158} antimicrobial peptides,³⁰³ monoclonal antibodies for bacterial infections and AMR.³	On a longer time horizon, it may be possible to see more regular use of personalised antimicrobial therapies in NHS practice, specifically using bacteriophages.¹⁴⁹ Another growth area could be personalised and engineered phages, including genomically engineered phages, to better target specific infections and resistant bacteria.^{151,162}
 Chronotherapeutics	Chronotherapeutics is an approach to treating diseases that considers our body's natural rhythms to identify the best times of day to give a person medication to make it more effective and to reduce side effects.	Considering treatment timing (e.g. cardiovascular diseases).³⁰⁴	Novel chronotherapeutic applications (cancer chemotherapy,³⁰⁵ medicine administration for patients with bipolar disorder).¹⁷⁴	After ten years, there may be further innovations informing personalised treatment administration, e.g. timing treatment in consideration of age, sex or chronotype (types of circadian rhythm). After this time, chronotherapeutics may also be a regular and embedded approach to multiple diseases, pending the production of evidence.

Table 4. The horizon for impact: where we are and where we can be with novel health tech paradigms for the NHS

Novel treatments	What are they	Existing applications	Potential in a 5–10 year time horizon	Longer-term impacts (>10 years)
 Technology and digital-and-data-enabled mental health	Innovation in mental health treatment is allowing us to use digital technologies (e.g. the internet, apps, chatbots and avatars) to deliver treatments for conditions like depression, anxiety and insomnia through talking therapies or other online therapies that help people change unhelpful thoughts and behaviours. This helps people get the care they need in timely ways and helps manage long waiting times for NHS mental health services.	NHS talking therapies using online and/or app-based programmes (depression, insomnia, anxiety)^{192–194} broaden options and patient access. Avatar therapy is offered for people who hear voices.¹⁹⁶ Digitally enabled triage pathways improve patient access and reduce workload for NHS staff.²⁰⁶	Improving access and scope for digitally enabled treatments could save staff time, improve the efficiency of mental health treatments and improve uptake by helping to overcome stigma.^{202,203,205} Digital and remote therapies can also help overcome logistical and geographical barriers to providing care,^{199,200,202,203,306} and help manage waiting times.¹⁹⁴ AI could expedite the review of complex case files and improve care efficiency.²⁰⁵ VR could be used for mental health services.¹⁸⁹ Collection of more and more diverse data could enhance understanding of mental health conditions and treatment impacts^{201,203,205,307} (e.g. Akrivia database creation efforts,²⁰⁸ NHS Talking Therapies data set³⁰⁸). Small molecule drug combinations, such as Cobenfy, could offer novel treatment for schizophrenia.¹⁸³	Beyond ten years, further improvements in AI and the integration of digital services could bring even greater gains in efficiency and patient outcomes.

Novel treatments	What are they	Existing applications	Potential in a 5–10 year time horizon	Longer-term impacts (>10 years)
 Functional restoration and BCI	These are novel techniques that can help people regain abilities they have lost. They can include technology that allows a person's brain to communicate via a computer or to give people physical (e.g. controlling prosthetic limbs) or cognitive abilities (brain stimulation to treat depression), improving quality of life.	Limited existing application in the NHS beyond specific cases (cochlear implants,²¹⁸ deep brain stimulation for Parkinson's,²¹⁹ and transcranial magnetic stimulation for depression^{220,221}).	BCI and neuromodulation could be further used to treat specific conditions, including those affecting ageing population²²⁹: retinal degeneration,²³⁰ substance use disorders,²³¹ neuropathic pain,²²⁹ immune function,²³² and others. It could help immobile patients to control prosthetic limbs and wheelchairs,^{247–250} or to enable patients to communicate,^{225–228} such as those with locked-in syndrome²²⁵ or quadriplegia^{226–228}.	Beyond ten years, BCI and related therapies offer the potential for curative treatment, better patient outcomes and autonomy,²³¹ and less long-term impact on the NHS and social care systems. It could offer non-invasive, personalised, long-term relief for conditions ranging from chronic pain to depression and restore function in severely disabled patients.
 Nanobots	These are minuscule, molecular-scale engineered devices designed to work inside a person's body and perform tasks like delivering medicine precisely to where the disease is located or helping repair damaged tissues.	Clinical applications are still being developed.	Unlikely to see impact at scale during a 5–10-year time horizon, given its early and experimental stage.²⁶²	Beyond ten years, nanobots could be applied for treating aneurysms,²⁶³ cardiovascular diseases,²⁶⁷ improve effectiveness and reduce side effects of cancer treatment,^{262,264} promote faster and more efficient tissue growth and healing,^{265,266} and tackle antimicrobial resistance.²⁶⁸
 Robotic surgery	This allows doctors to use machines with robotic arms to help perform operations very precisely to support better outcomes for patients, faster and less painful recovery after the surgery.	Established technology with a relatively high degree of adoption within the UK (especially for urology surgery).^{252,253} Adoption continues to increase.	The potential for smaller robotic systems,²⁵² which may also be more cost-effective,^{258,309} and to incorporate AI and other technologies to increase the capabilities of the device towards semi-autonomous or autonomous surgery.^{252,310}	Beyond ten years, robotic surgery might be further applied for inter-vascular²⁵² and microsurgery procedures,²⁶⁰ while also transforming the training of surgeons.

Novel treatments	What are they	Existing applications	Potential in a 5–10 year time horizon	Longer-term impacts (>10 years)
 Smart pills	These are small pills with sensors or cameras that can gather information in a person's body to help diagnose conditions, monitor treatment effectiveness or deliver medicines in ways that are easier for patients and the NHS (e.g. pills instead of injection).	Current applications for diagnosis²⁷⁰ (e.g., capsule endoscopy).²⁷³ The application of drug adherence monitoring has not gained wider use in practice.²⁷⁴	Potential to expand diagnostic smart pills such as for motility testing and measurement of pressure, pH, transit time and temperature^{272,283} for gastrointestinal diseases.	Beyond ten years, smart pills could offer a novel, painless, minimally invasive way to deliver drugs such as GLP-1 agonists and RNA molecules through the GI tract wall, including an option without any needles, reducing the risk of tissue damage.²⁸⁴ Smart pills could deliver local treatment for GI diseases such as inflammatory bowel disease²⁷⁷ and reduce side effects of treatment.²⁷⁰ They could also offer an alternative, easier way of administering drugs that are currently available only as injections and increase adherence.²⁷⁸ They could also offer non-pharmaceutical treatment for conditions such as obesity or constipation.²⁷⁰

Box 12. A vision for the future of treatment in the NHS

In a vision for the future of treatment in the NHS:



Precise and personalised biological and health technology treatment approaches will improve patient outcomes and the efficiency and effectiveness of NHS services.



New types of therapeutic approaches will reduce the need for repeated treatments and hospitalisations, improve access to care and help address unmet needs.



Novel treatment approaches will help address major public health challenges, including those related to social inequalities.



Being a world-leading location to trial innovative treatments, alongside efforts to secure access to treatments, will deliver health and economic benefits.

A future vision for novel treatment paradigms in the NHS

In a future vision for success, the development and adoption of novel treatment approaches in the NHS could significantly benefit patients through more effective, longer-acting and personalised treatments for chronic and infectious diseases. It could also reduce pressures on staff capacity and resource wastage due to inferior treatments and adverse drug reactions and help address inequalities in access to treatment for conditions disproportionately affecting underserved populations. In light of our analysis of novel treatment paradigms, their current impacts and future potential, if a future vision for novel treatment paradigms in the NHS is successfully enacted, four key benefits for patients and the NHS could be achieved within ten years. These benefits are summarised in Box 12 and expanded on in the contents that follow.



1. Precise and personalised biological and health technology treatment approaches will improve patient outcomes as well as the efficiency and effectiveness of NHS services.

To illustrate, and as elaborated on in section 2 above, genomic medicine is already enabling more personalised therapies for diseases like cancer and rare diseases. It also helps clinicians make better decisions about prescribing treatments that patients are more likely to respond to well, reducing the wastage of NHS resources on ineffective medicines that may not be tolerated well by patients. Other novel biological treatments like nanomaterials are also beginning to support better patient outcomes by precisely delivering treatments to specific places in the body. Other benefits in personalised, more efficient and effective care could be achieved by changing *when* rather than *what* a patient is treated with by harnessing the science of chronotherapy. Advances in novel health technology approaches like robotic-assisted surgery are also helping patients receive more precise and

personalised treatment. In the future, robot-assisted surgery could lead to wider scale impacts across a broader range of surgical conditions if technological performance and cost-effectiveness improve. Within the next ten years, there is a wealth of opportunity to scale up these types of personalised treatment approaches to more diverse conditions and to benefit more people at a greater scale. Other areas of more personalised treatment innovation, such as smart pill technologies and personalised microbiome-based treatments, also promise to transform healthcare. However, given the current state of developments, impact at scale will likely require a longer time horizon to materialise.



2. New types of therapeutic approaches will reduce the need for repeated treatments and hospitalisations, improve access to care and help address unmet needs.

Long-acting treatments have scope to reduce pressures on NHS capacity. As discussed in Section 2, some long-acting therapies are already used in the NHS for conditions like HIV³¹¹ and cancer (novel synthetic biology-based CAR-T therapies for blood cancers), enabling patients to get fewer and more effective, longer-acting treatments. In addition, some regenerative medicine applications have been tested in the NHS (e.g. for trachea and hip repair) and show promise in reducing the need for repeated surgeries or treatments and improving patient quality of life. As discussed in section 2, there is further potential to expand on the current applications of long-acting novel treatment approaches in the future (e.g. CAR-T applications for a broader range of cancers, monoclonal antibodies for COPD, gene editing therapies for heart disease, dementia and muscular dystrophy; expanding regenerative medicine to new clinical areas). New preventative and therapeutic applications of mRNA vaccines

are also being explored in areas like influenza and cancer. In addition to novel biological paradigms, novel health technology treatment approaches are also helping improve timely access to care in areas of major unmet need and public health challenges (e.g. digital mental health therapies for depression, anxiety, insomnia, and schizophrenia) as well as bringing hope to patients with conditions which historically have seen less innovation (e.g. functional restoration technologies to restore mobility to paralysed patients). In the next ten years, there is scope for these treatments to benefit more people, from digitally-enabled mental health treatments to neuromodulation approaches, which could enable immobile patients to restore movement functions and enable patients who cannot communicate via devices. It is also important to consider interactions between medical and wider public health behavioural interventions, including mental health talking therapies and exercise,³¹² in helping people stay healthy, preventing deterioration and unnecessary hospital admissions.



3. Novel treatment approaches will help address major public health challenges, including those related to social

inequalities. Novel therapies can help the NHS to address public health and wider societal health challenges (such as helping people to be well enough to work, thereby helping to tackle inequalities). For example, as discussed in section 2, drugs used to treat obesity and diabetes (such as novel GLP-1 agonist formulations or RNA interference therapies) could help address major public health concerns like obesity, diabetes, hepatitis B and liver damage. Even so, progress will depend on addressing affordability and pricing challenges and delivering care alongside other public health interventions considering the wider social determinants of health and behavioural

change. Further research is ongoing into novel application areas for GLP-1 agonists, including in depression and alcohol addiction. Another major public health challenge - antimicrobial resistance – could be tackled with the help of innovative alternatives to antibiotics (e.g. bacteriophages, monoclonal antibodies), provided that the right incentives and enabling infrastructure for innovation are put into place. While some implementation may happen in the next ten years, wider scaling could require a longer time horizon.



4. Being a world-leading location to trial innovative treatments, alongside efforts to secure access to treatments, will deliver health and economic benefits.

The United Kingdom is a medium-sized market for innovations compared to some other high-income countries (either due to the size of their populations or approaches to paying for innovative medicines), which have the advantages of different pricing models and/or larger populations, and hence cannot compete on cost factors (i.e. prices it will pay industry for novel medicines). However, the UK has global strengths in life sciences and health technology research and development, and it has the NHS. Patients participating in clinical trials have opportunities for early access to treatments (although wider-scale NHS adoption would be needed for more patients to benefit), and NHS organisations active in research are linked to high-quality care.³¹³ In addition, commercial trials attract revenue to the NHS while wider research and innovation activity attracts investment and can support knowledge-based industry, as we highlighted in Section 2 for the genomics sector as an example. If people remain healthy, they are more likely to be working, which can contribute to the wider economy. For example, one study found that talking therapies for people with mental health conditions can increase

economic productivity by helping people return to work and reduce welfare benefits by over £650 per person within two years of receiving therapy.³¹⁴ Future advances in biological and health-technology treatment paradigms could scale up patient, NHS and wider societal and economic benefits. There is significant untapped potential to make better use of the NHS as a unique base for clinical trials.

Three key transitions in how the health system functions would accompany efforts to realise this vision for success and ensure that patients and the NHS benefit from new treatment approaches at scale.

Reflecting on the findings presented in section 2, and in light of the vision for what good would look like in relation to novel treatment paradigms that we have laid out, there are some fundamental transitions in perspectives and practices on what constitutes a good health system that would need to accompany efforts to realise the vision. These transitions are the result of interdependent developments and opportunities created by scientific and technological progress in healthcare (across prevention, diagnosis and treatment spaces) and changing health system landscapes (such as the focus on more integrated care).

- 1. The first transition pertains to how services are commissioned: The way the NHS commissions services would evolve to focus on commissioning 'a package of solutions' considering needs across the care pathway rather than focusing on individual products or technologies.** In practice, this means thinking about the problem that needs solving and considering the combinations of products, technologies, and services that need to be put in place to address the unmet need appropriately. This approach to commissioning would include better

integration of diagnosis and treatment, as well as pharmacological and non-pharmacological interventions, including commissioning solutions that combine treatments with lifestyle changes (e.g. social prescribing). This could help the NHS to deliver personalised treatments to patients and also bolster efforts to address major public health challenges and provide alternatives to hospital-based treatments. For example, advances with novel biologics such as GLP-1 agonists for obesity³¹⁵ could complement lifestyle and behavioural change interventions for more effective and longer-term patient benefit (Int 14). In addition, there is much potential in exploring no-tech novel treatment paradigms such as chronotherapy, which focuses on optimising the timing rather than the type of treatment, and in considering commissioning services enabling such personalised treatment approaches. This transition can be partly enabled by knowledge brokers between the public and private sectors to enable better communication between innovators and payers (Int 3).

2. **The second transition pertains to duration and frequency of treatment: The NHS would shift its focus from providing ongoing, repeated treatments in hospitals or ongoing repeat prescriptions for long-term conditions to offering more innovative treatments with one-off or relatively limited numbers of administrations.** This could help decrease pressures on the health system by reducing the need for frequent hospital visits and hospital beds. Some examples of areas with particular potential include curative/ultra-long-acting treatments like CRISPR and certain cell therapies (e.g. CAR-T therapy),^{62,290–292,294} CRISPR-based therapy for treating sickle cell disease and

transfusion-dependent β thalassaemia¹⁰ that disproportionately affects specific populations as well as long-acting oligonucleotides, long-acting peptides and monoclonal antibody injectables,^{316,317} and regenerative medicine therapies (e.g. for hip replacement^{87,88} or sickle cell disease⁹⁸). However, further evidence will be needed on long-term effects, cost-effectiveness and savings for health systems over an individual's life course, given high initial costs, which currently pose a bottleneck to scale and spread.

3. **The third transition relates to more long-term funding for interdisciplinary research and innovation and sustainable interdisciplinary research careers. The funding of innovation efforts to develop better treatments would shift from more discipline-focused funding approaches to ones focused on funding interdisciplinary efforts to enable advances from biology, engineering, computing and data science to better catalyse innovation in treatments.** While improvements in funding interdisciplinary research have been made over time, it is still challenging to pursue interdisciplinary research careers. In the innovation space (e.g. developing novel treatment approaches), there is still untapped potential for more interdisciplinary efforts. This transition could help develop more effective treatments more efficiently and ultimately help NHS clinicians make better-informed treatment choices for patients. Synthetic biology is a prime example of the potential of disciplinary convergence (between genomics and engineering) to support more effective treatments for diseases affecting large populations and to improve NHS care. Examples of innovative treatment emerging from interdisciplinary research include CAR-T

cell therapies for cancer, which allow for shorter treatment durations and potentially longer-lasting effects than chemo/radio-therapy,⁷⁶ as well as mRNA vaccines for fighting pandemics³¹⁸ and improving drug delivery, including for rare diseases (e.g. lipid nanoparticles used in treatment of hereditary transthyretin amyloidosis⁴⁶). With this transition, research funders would embrace funding more interdisciplinary collaborations and projects between biologists, chemists, engineers, data scientists, ethicists, implementation and behavioural scientists. In turn, research institutions may embrace more interdisciplinary career pathways. Part of this transition would also include a transition from a digitally nascent to a digitally mature NHS which makes better use of AI and machine learning (ML) with due caution

and exercise of clinical judgement. AI applications have the potential to inform better treatment choices^{319–322} (through better patient stratification, predictive analytics, clinical decision support, optimising performance of digital therapeutic interventions such as chatbots and virtual reality settings) and make more efficient use of NHS staff time and skills (supporting clinicians with their regular tasks, including note-taking). AI applications can also inform and advance drug development^{319,323} (efficiently identifying drug targets and optimising treatment design, especially for more mature modalities such as small molecules, antibodies and oligonucleotides where there is a substantial amount of existing information available to train AI with).

Chapter 4. From prospect to practice: seizing the opportunity and enabling the future vision for impact from novel treatment paradigms in the NHS

There is an opportunity and an urgency to arrive at a strategy and an actionable implementation plan to ensure novel treatment paradigms help transform the NHS and support its sustainability and excellence in patient care that the UK population deserves. The biggest opportunities relate to creating a supportive ecosystem for innovation in treatment in and around the NHS. Such an ecosystem would act as a platform to catalyse and nurture the advancement of novel treatments and their adoption into everyday NHS practice. However, the maturity of a treatment/technology area should be considered in the prioritisation of investments and to ensure realistic and measured actions.

Below, we outline key opportunities to shape the ecosystem to support an innovative NHS as it relates to novel treatment paradigms.

We focus on opportunities related to seven support mechanisms fundamental to achieving success in transformation efforts with novel treatment paradigms and discuss how they can be enacted to support a vision for success.¹² These relate to: (1) workforce (capacity, skills, capabilities, incentives, accountabilities); **(2) information, evidence and data** environments; **(3) physical infrastructure;** **(4) funding, commissioning and procurement for developing and adopting novel treatment paradigms;** **(5) R&D governance and regulation;** **(6) collaboration and coordination in treatment development and adoption;** and **(7) patient and public involvement, engagement and participation, including in light of inequalities.¹² We also outline 15 key actions associated** with the opportunities and support mechanisms discussed.



Opportunity 1: **Nurture an NHS workforce trained and incentivised to engage with innovation in new treatment paradigms for the benefit of patients and the quality, safety and value for money of health service delivery. This will empower NHS staff to deliver evidence-based and innovative patient care.**

Action area: Workforce

1. Integrate training on research and innovation related to novel treatment priorities into professional education and development (e.g. technical skills to deliver novel treatments).
2. Provide resources for staff to support the adoption of novel treatments (e.g. via job structures and career pathways, ring-fenced time, reward and accountability for best practice).

Novel treatment paradigms require a trained workforce that is enabled to deliver more personalised medicine. For example, a critical mass of NHS staff and interdisciplinary teams combining skills in genomics, proteomics, ethics and data science will be needed to ensure that scientific advances in genomics reach the health service and patients and result in improved care quality, patient outcomes and experiences. Similarly, making the most of advances in regenerative medicine and synthetic and engineering biology will require a skilled workforce capable of supporting the complex processes involved in developing and delivering innovation in the NHS. For example, new skills will be needed to enable the safe and effective delivery of CAR-T cancer therapies (Int 3). As another example, realising the potential of phage therapy to help combat antimicrobial resistance will require NHS staff to know how to access people skilled in identifying phages that would be effective for specific types of patients and diseases.¹²⁴ Training will also be required for NHS centres to be able to test bacteria susceptibility to phages.¹²² Surgeons will need to be trained to utilise new robotic surgery techniques.^{254,255} Implementing brain-computer interface (BCI) and neuromodulation therapies will require training clinical and technical staff,²³⁰ and might even necessitate the creation of a new dedicated sub-speciality not specific to a disease area.²²⁹ Across all

treatment paradigms, it is key to ensure that the workforce has the skills needed to embed novel solutions into care pathways. This is particularly true as professionals of technology and medicine do not intrinsically share the same vocabulary or understanding of problems, but need to interact throughout innovation process so that new products effectively target unmet NHS and patient needs. While not every member of NHS staff needs to be an innovator or research active, more staff need to understand innovation and how it can help the NHS and patients.¹²

In addition to training, there will be a need to raise awareness amongst NHS staff on available novel treatment options they can access and deliver to patients, supported by clear guidelines on patient eligibility and referrals, particularly in areas such as the microbiome, chrono-therapeutics, and tech-enabled mental health interventions. The potential for a trained workforce to deliver novel treatment paradigms will depend on clinical, administrative and operational leadership support in the NHS, which can ensure permissive, enabling and accountable environments (e.g. buy-outs of time for training, embedding training and engagement with novel treatment paradigms in job roles and career pathways, and strengthening accountability regimes for adopting best practice).



Opportunity 2: Build on existing infrastructure and renew public engagement efforts to make it easier to collect, share and access data, information and evidence related to novel treatment paradigms - for research and innovation purposes (including trials). This will help ensure an evidence-powered NHS delivers excellent, cost-effective treatments and care and help unblock bottlenecks to achieve more personalised medicine at scale.

Action area: Data, information and evidence

3. Invest in a functional data access and sharing infrastructure. Better data access, sharing and linkage can enable research and innovation to develop new treatments and support their adoption. This needs to be secured using a mix of technical solutions that can help ensure data privacy and security, regulation, effective public engagement and public trust. There is an opportunity to build on more developed data environments already in place (e.g. genomics/multi-omics and genomic medicine). Using existing digital infrastructure (such as potentially the NHS App) could also help establish better ways of raising awareness, recruiting patients into clinical trials and enabling patients to decide what data they are happy to share. The newly announced partnership between the UK Government and Wellcome to establish a new health data research service is a promising development.³²⁴
4. Fund and steer an evidence pipeline for data on emerging treatments (such as promising developments in gene therapies, mRNA vaccines and digitally enabled therapies for mental health) from clinical trials and real-world implementation studies. This can help secure accountable, evidence-based practice and inform the business case for NHS commissioning (e.g. long-term clinical and health economic impact data to inform optimal eligibility criteria and better data on clinical and cost-effectiveness of robotic surgery).

Better data access, sharing and linkage can enable new application areas through better prediction of needs, timelier intervention and better health system resource allocation across the population and over the life course. For example, the success of applying genomics to achieve more personalised medicine at greater speed, spread and scale will fundamentally depend on an improved and linked data infrastructure that brings together genetic, proteomic, behavioural, lifestyle and clinical data. AI applications to accelerate drug discovery and improve clinical decision support and predictive analytics could also inform optimal treatments. The public would need to buy in and support data sharing and access to enable the evidence base for progress. Regulatory interventions and

technical solutions to ensure data security and privacy, as well as effective public engagement and participatory research, will be needed to achieve this.¹² While digital integration between the NHS and researchers is a well-known challenge, it is necessary to resolve this issue, including with the right skills within the NHS, to enable better innovation (Int 11).

Investing in R&D to improve the clinical evidence base for more nascent treatment areas, as well as in health economic evaluations and social and implementation science research, will be critical for a smoother translation of advances from lab to clinical practice. Examples of where R&D investments can catalyse needed progress include improving our understanding of

epigenetics and the complex interactions between genetic and environmental factors³²⁵ to help validate and ensure treatment safety and effectiveness³²⁶; enhanced trial activity to gather evidence on the stability, safety and efficacy, optimal dosing and delivery systems for phages, antimicrobial peptides and mRNA therapies^{3,151,327} (Int 8), improving evidence on the safety of mRNA therapies to potentially inform adaptations and reformulation of vaccine technologies, and research to improve clinical and applied knowledge in relation to the microbiome. The evidence base for digitally enabled therapies for mental health requires further investigation, especially with real-world application,^{192,196,328} building on wider initiatives to improve collection and linkage of data on both physical and mental health throughout the NHS and beyond. It also requires generating and using data that reflects the diversity of patient populations (e.g. training AI models to provide accurate predictions for diverse populations).

Collecting and scaling data and evidence from both clinical trials and real-world

implementation studies will be crucial for informing the business case for commissioning and procurement in the NHS and for supporting the scale and spread of novel treatment paradigms (Int 8). This includes collecting long-term impact data (clinical and health economic) for novel treatment paradigms with potential for impact on a large proportion of the population (such as GLP-1 agonists for which there are currently still many unknowns about long-term effects¹¹² including risks and their management (Int 14) and optimal eligibility criteria). Some areas require specific frameworks to progress, such as neurological data, which raises distinctive concerns of ownership and governance for implanted brain-computer interfaces (BCIs),³²⁹ as well as a lack of post-market surveillance that could exacerbate risks associated with these devices.³³⁰ To address these issues, regulators from various fields should collaborate to establish definitions and processes for neurodata.^{330–332}



Opportunity 3: Prioritise funding of R&D and trials into novel treatment paradigms such that science and technology areas which are more mature are supported in a way that can catalyse and accelerate translation into NHS service delivery while more speculative but potentially transformative therapeutic paradigms continue to receive targeted and gradual R&D support. This will ensure fewer bottlenecks for innovative solutions reaching patients, and staff well-being will be improved, including through pride in delivering world-leading care.

Action area: Funding, commissioning and procurement

5. Prioritise investments considering the levels of technology maturity and potential for impact in light of disease burden or disease neglect innovation-wise and the scale of health improvement it can offer (including scope for long-term improvement). Using frameworks such as Technology Readiness Levels can help understand which types of novel solutions might be most ready for adoption in the NHS and which types of solutions in development need R&D support.
6. Use methods and tools such as horizon scanning, consensus exploration and target product profiles (TPPs) to provide a clear demand signal to innovators and maximise the chances of new treatments meeting NHS needs. Set clear expectations for the adoption of new treatments in terms of both technical performance criteria and criteria related to cost and fit with NHS care pathways, with an advance commitment to support those that meet the requirements. In doing so, consider the need to balance national priorities and regional and local population-specific needs.
7. Create longer-term budget cycles and more solution (over product) focused commissioning approaches in the NHS to enable more strategic and realistic approaches to the commissioning of new treatments, helping fix funding flows and recognising value, including in the context of overall cost-savings for the NHS and other spheres of government over time. This could help mitigate the upfront investment needed for some treatments (e.g. long-acting gene and cell therapies and regenerative medicine, GLP-1 agonists for obesity, advanced medicines for respiratory diseases and robotic surgery). What could be commissioned centrally and what regionally and locally in a more solutions-focused approach merits attention.
8. Reinvigorate the clinical trial landscape, making the most of the potential of the NHS as a testbed for trials of innovations focusing on novel treatment paradigms.

Public investment into R&D, clear commissioning and procurement criteria and pathways into the NHS are the necessary (but not sufficient on their own) incentives for innovation. Public funding of both R&D and funding for innovation uptake have been fundamental for spreading and scaling novel genomic treatments across the NHS Genomic Medicine Service and reducing uncertainty

about rewards for innovation efforts (Int 2). Public investment helps further mobilise downstream capital from the private sector.³³³ Investment decisions need to consider factors such as (1) the maturity of scientific and technological development in a given novel treatment paradigm area (how ready the technology is for adoption and in need of funding for adoption, how nascent it is and in

need of R&D funding); (2) the scope and scale of impact an innovative treatment could have in addressing a condition of high disease burden or high neglect innovation wise (for many people, for underserved groups), as well as (3) the scale of potential improvement in health it could offer (significant improvement, modest improvement).

For effective R&D investment, a sustained funding stream is needed to maintain a top-quality research and innovation pipeline in treatment paradigms of key strategic importance. There is potential to capitalise on areas where the UK already has established strengths (e.g. genomics, synthetic and engineering biology). However, these strengths and the UK's globally leading position in areas like genomic medicine and engineering biology cannot be taken for granted. For example, publication outputs in engineering biology have been slowing down, and average grant sizes are reducing, while some other global leaders have recently pledged additional investment.⁷⁴ For neurotechnology, the UKRI invested £9m annually in research related to neurotechnology between 2011 and 2020, which is small compared with Australia, Korea, the US, Canada, the EU and Japan.²³⁰

The readiness of the NHS for adoption needs to be borne in mind in addition to factors influencing the value of the innovation, as well as considerations around where in the health system innovation could make the biggest difference (e.g. primary care, secondary care). Innovation that offers the potential to 'interfere' and treat disease early in its development and prevent deterioration can make a big difference for patients (Int 11).

Clear demand signals from policymakers and payers to innovators can help align the supply of research and innovation with demand and willingness to pay. Methods and tools such as horizon scanning, consensus building and target product profiles can help support

effective demand signalling for research and innovation needs.³³⁴ A better alignment of supply and demand is likely to support more efficient use of limited financial resources in the system, considering care pathways and innovation needs.

Longer-term budgeting cycles in the NHS, coupled with more sophisticated economic modelling approaches, could also help support strategic and realistic approaches to decision making and understanding value, including in the context of overall cost-savings for the NHS³³⁵ from novel treatment paradigms.

This could enable more informed decision making about the introduction and roll-out of initially expensive, but potentially cost-effective in longer-term, therapies. Demonstrating the value would also improve political acceptability (e.g. for long-acting gene and cell therapies and regenerative medicine, as well as oligonucleotides and oligopeptides requiring multiple doses over time but each with a lasting effect, and GLP-1 agonists for obesity). Such therapies, while expensive, could deliver not only health but also wider socioeconomic benefits (e.g. employment, labour productivity, reduction of co-morbidities). Long-acting treatments could help significantly decrease pressures on the health system (reducing the need for repeated treatments or hospitalisations) but are more expensive and often require payment upfront. Currently, they require better evidence on long-term cost-effectiveness or savings for health systems over the life course of an individual and population, which poses a bottleneck to scale and spread. The scale and spread of novel treatment paradigms call for more sophisticated economic modelling approaches, capturing not only direct impacts on patients but also wider health system and economic benefits compared to the lifetime cost of treatment with incumbent treatments. It is also useful to consider areas where there has

been rapid adoption ahead of formal economic evaluation of benefit, such as for robot-assisted surgery, and assess what lessons can be learned more broadly. In addition, when making adoption decisions, it is important to consider whether the benefits for patients and the NHS from an innovation are greater than making an existing option more accessible.

Along with longer-term budget cycles, a solutions-focused commissioning approach could also help reinforce strategic commissioning and mitigate the upfront investment needed for some treatments.

A solution-focused approach would focus on commissioning combinations of pharmacological and non-pharmacological interventions (e.g. behavioural, technology-enabled) across a patient care pathway (i.e. prevention, diagnosis, treatment) to help deliver optimal patient outcomes most cost-effectively. Within this approach, it would be important to consider what types of solutions or interventions within them could be commissioned centrally (i.e. with the NHS as a single-payer system) and which would need to be commissioned at regional and local levels, with authority decision making on the optimal intervention devolved. When commissioning novel care pathway solutions and treatments within them, it is important to consider the full costs of embedding novel treatments into care pathways, including equipment, infrastructure and staff training needs to enable effective

implementation, rather than just the costs of the intervention itself.

There are significant opportunities to attract more investment into clinical trials in the NHS, providing a means for participating patients to get early access to treatment.

The UK cannot compete on cost in the same way less price-sensitive markets with larger populations can, and keeping companies in the UK is a challenge given that it is easier to attract investment into R&D and for products to reach the market in some other jurisdictions (Int 3, Int 10, Int 11).³³⁶ But the NHS presents a unique opportunity for enhancing trial activity to support early patient access to treatments, at least for some patients. This however cannot come at the expense of not adopting best practices and proven, novel, cost-effective treatments across the NHS.

Funding considerations also need to be considered in the context of supply chain sustainability. For example, phages are not frequently commercialised by companies due to the high financial costs of manufacturing, alongside some challenges with clear regulatory approval pathways and clarity on what is patentable.¹²⁴ Given high manufacturing costs, government funding may be needed to make it commercially viable in the UK, as in other countries where phages have been incorporated more into clinical care.¹³¹



Opportunity 4: **Establish the UK as a leader in regulatory efficiency and innovation for an era in which technology and disciplines are converging and creating new opportunities for patient and NHS benefit. This will help ensure that the NHS is more active in research and trials so that patients benefit from quicker access to novel solutions, and the NHS benefits from revenue and royalties associated with trials and innovations and a reputation for care excellence.**

Action area: R&D governance and regulation:

9. Ensure a more streamlined, single overarching R&D approval process (learning from efforts to streamline ethics approval processes) across the NHS, alongside a national training programme for staff working in R&D offices.
10. Establish clear and flexible regulatory processes for new treatments (e.g. standardised protocols for manufacturing and preparation of antimicrobial phages, regulatory sandboxes in synthetic biology, regulation related to neurotechnology and new forms of data and the potential for influencing cognition).

From an R&D governance perspective, researchers often need to navigate highly variable practices in different NHS settings.

In genomics, proteomics and personalised medicine, most major institutions within the system have consent for the reuse of data, but data-sharing models and agreements require further attention, and data linkage continues to pose a challenge. Although the UK Biobank now has access to cohort data from both primary and secondary care, the previous lack of information has imposed limitations on how UK Biobank data can be utilised.¹²

Regulatory pathway clarity is key for innovators to be able to navigate requirements for approval and uptake of novel treatment paradigms in the NHS. At present, greater regulatory clarity is needed for a range of novel treatment prospects (Int 3). For example, this applies to phage therapy and standardised protocols for characterisation, manufacturing and preparation of phages¹³⁵ that could support innovative phage cocktails becoming licensed and approved for use. In synthetic and engineering biology, the National Vision for Engineering Biology aims to utilise

the new Engineering Biology Regulators' Network to establish regulatory sandboxes, creating pathways for development.⁴² For neurotechnology, significant regulatory uncertainties hinder progress (such as the generation of new forms of data and the potential for influencing cognition). For example, although implanted BCIs have been used in clinical trials since 1998, none have been approved by regulatory agencies.³²⁹ Regulating AI applications in healthcare treatment is also an area in need of further clarity and progress in balancing pro-innovation approaches with appropriate quality control and safeguarding.^{337,338}

Regulation must also tackle safety and security requirements cautiously while supporting an efficient pro-innovation environment. Regulators need the requisite skills to provide oversight of novel science and technology developments and demonstrate that they can provide value rather than hamper innovation while at the same time ensuring requisite safety controls. The skills for regulating technology platforms (applicable to multiple diseases) or convergent technologies

(e.g. based on combining developments in biology and computer science) may need updating in regulatory agencies in order to deliver efficient regulation (Int 11). The types of evidence required may also differ from the traditionally used randomised clinical trials. For example, the oversight of engineering biology is fragmented globally, featuring disparate mechanisms and creating obstacles to international collaboration. A greater international alignment could facilitate cross-sector collaboration and international biosecurity measures, given potential risks (e.g. potential for bioweapons).³³⁰ In some areas of microbiome-based innovation, like faecal microbiota transplantation, stringent enforcement of quality controls on faecal material processing and testing is also needed. In areas like regenerative medicine and stem cells, safety and ethical concerns over using stem cells need to be addressed.³³⁹ The key is for regulation not to be unnecessarily stifling or overly bureaucratic and to deliver on innovator needs for agility and efficiency. Early regulator engagement with products and technologies in development and closer working between R&D governance and regulatory bodies may support more efficient regulation and proactive regulator support for research and innovation efforts, potentially speeding up timelines to impact.

The regulatory environment, particularly in clinical trials, will be crucial in maintaining competitiveness in pharmaceutical markets, with the NHS playing a significant role.³⁹ There is also significant potential for closer work between R&D governance, regulation, and HTA bodies. There is a need for faster and leaner regulation and health technology assessment, with bureaucracy and inefficiencies currently disincentivising innovators to develop, test and launch their treatments in the UK. For example, in the area of regenerative medicine, NICE was recommended to review and update its evaluation processes for regenerative medicine, specifically assessing long-term benefits and potential NHS savings.⁸⁹ There is also significant potential for developing standardised guidelines for the timing of therapy administration across different medical applications, which would help streamline the implementation of chronotherapeutics. There is learning to be gained from how the US FDA has approached this^{140,329} in approving technologies developed to deliver medications to the body that consider the biological rhythms of disease.³³⁰ Many novel treatment paradigms (e.g. synthetic biology, genomics and multi-omics) rely on the convergence of disciplines and require novel regulatory skills and processes that can handle the unique requirements that technologies combining biomedicine, engineering, IT, quantum computing and AI bring into play.



Opportunity 5: **Enable the NHS to make the best use of modern high-tech facilities and equipment for novel treatment paradigms by ensuring that capital investments support the pre-requisite basic facilities, computer equipment, WiFi and IT systems that need to be in place.** Without the basics, it will not be feasible for the NHS to make the best use of high-tech infrastructure.

Action area: Physical infrastructure:

11. Ensure that the underpinning physical and technical infrastructure is in place to scale priority new treatments (e.g. to deliver CAR-T therapies or mRNA vaccine manufacture), including functioning basic IT systems, hardware and Wi-Fi and safe physical environments. This requires carefully considering capital investments into the facilities in which novel treatment paradigms will be delivered so that they align both the fundamental necessities and advanced innovation needs. It also includes making sure that the staff who need to operate and maintain modern treatment equipment and laboratories are in place and well-trained to deliver their roles.

There is already strong infrastructure in some areas to build on to support further benefits from the rollout, spread and scale.

A key example is the Genomic Medicine Service infrastructure. However, despite current infrastructure investments, wider NHS infrastructure needed to scale gene therapy and CRISPR treatments remains a challenge. This applies to both data and IT infrastructure in the Genomic Medicine Service,^{331,332} as well as to the infrastructure for gene therapy treatment delivery in practice, involving cell processing, manufacturing, freezing and shipment.³³³ These therapies are complex and time-intensive and would require consideration of whether cell modification would be conducted centrally or locally and how this would be facilitated by workforce changes. In addition, existing NHS microbiology services also provide an existing foundation to support the rollout of phage therapies to help combat AMR (e.g. UK Phage Therapy service and National Phage Library) and create opportunities for patients to be seen in their regular care settings – with access expanded from hospitals to primary care.¹⁴⁹

However, further investment in specialised research, innovation and manufacturing infrastructure and facilities is needed,

for example, to deliver CAR-T therapies, to prepare and test personalised phages to ensure effectiveness for individual patients.¹²⁴ Specialised CAR-T centres already exist in the UK, and future planning of demand should inform further potential infrastructure and capacity needs. In the microbiome area, both FMT delivery capacity and stool banking capacity and facilities will underpin the potential to scale. Improved and efficient storage and manufacturing facilities and practices also have a role to play. One area where this is needed is phage production and phage banks.¹²⁴ Another is facilities to enable speed and scalability of mRNA vaccine manufacture. Biofoundries are also important for the manufacture of novel synthetic-biology-enabled treatments and for designing, building and testing engineered biological systems in an efficient and scalable manner. This is a global challenge, with countries like South Korea investing heavily in biomanufacturing infrastructure.⁴² For other areas like regenerative medicine, facilities and equipment

that enable patient cell manipulation are needed, and many hospitals in the UK do not yet have the facilities to do this. Spanning all of these needs is securing efficient AI-powered platforms and IT, data and cloud computing infrastructure and ensuring good links and clusters that can bring together academia, research institutes, the NHS and industry. The UK already has vibrant bioscience clusters but novel treatment paradigms are likely to call for further strengthening of some cross sector relationships, especially around the

convergence of disciplines involved in health innovation (e.g. relationships between health and engineering organisations).

Importantly, the appropriate use of high-tech facilities for novel treatment paradigms cannot be secured without investment in basic NHS infrastructure. This includes the need for functioning basic IT systems, hardware and WiFi and safe physical environments in NHS organisations.



Opportunity 6: **Make the most of opportunities to bring health policy and industrial policy efforts closer together to ensure effective, coordinated investment into R&D and trials and the effective translation, spread and scale of novel treatment paradigms in the NHS for health and economic benefit.**

Action area: Collaboration and coordination

12. Establish a cross-sector governance and coordination arrangement for funding and orchestrating initiatives that can support the pathway from R&D through to adoption, scale and spread. This should include closer coordination between regional and national efforts, between industrial and health policy bodies and funders, and between R&D governance, regulatory and health technology assessment bodies.
13. Create a community of practice (nationally and internationally) around novel treatment paradigms involving clinical, health services, biomedical, engineering, and data science expertise, as well as public and patient voices and industry. In key strategic areas (e.g. genomic medicine, synthetic and engineering biology, regenerative medicine), the UK already has established collaborations that provide a basis.

Delivery of many treatment paradigms is complex and requires coordination across NHS settings and public and private sector collaborators. For example, delivering CAR-T therapies requires taking a patient's blood, sending it to the manufacturer's laboratory, transforming T-cells, transporting it back and administering it to the patient.

Both national and international collaboration and knowledge exchange are key. In many key strategic areas (e.g. regenerative medicine, synthetic and engineering biology),

the UK has already established national and international collaborations, which need nurturing.⁴² Nationally, there is scope for further collaboration and coordination, including horizon scanning for homegrown and international solutions in development with the potential for trailing and adoption in the NHS. Within and beyond the UK, creating arrangements and incentives for organisations is another key area of action to ensure equitable collaboration between organisations of different sizes (Int 10).



Opportunity 7: There is an opportunity to build on the UK's strong foundations for patient and public involvement further to bolster the diversity of patient and population groups that have a say in the design, development, and implementation of novel treatment paradigms in the NHS. This could improve trust and the relevance of novel solutions embedded in a wider government ambition for a fairer UK.

Action area: Patient and public involvement, engagement and participation:

14. Pursue timely public and patient consultations and engagement around potential questions (e.g. ethical considerations, equality in access, eligibility). Personalised medicine requires patients to commit to data sharing with confidence, for which an unfortunate legacy of past concerns needs to be overcome.
15. Address inequalities by ensuring the relevance of new treatments for a full range of Britain's population and access to them. Consider population diversity in determining what research and innovation is prioritised and how it is conducted (i.e. with whom as participants or patient and public involvement advisors).

Personalised medicine demands a participatory healthcare model, where patients have increased awareness and control over their health management.³³⁴ This approach requires patients to commit to data sharing with earned confidence and trust and actively participate in designing research, innovation and healthcare services, which can be facilitated by enhanced health literacy and understanding of research, innovation and data uses.

Active public engagement outreach and transparency in ways of working of initiatives involved in developing novel treatment paradigms could help catalyse more diverse participants in research and innovation and lead to more accurate and relevant therapies, helping reduce inequalities and increase public trust. For example, 80% of genome-wide association studies currently focus on individuals of European ancestry,^{335,336} although progress is being made with initiatives such as the Genomics England Diverse Data initiative. Public engagement efforts also need to engage with ethical concerns about the risks of, for example, health insurance companies taking

advantage of this data to assess individuals also need mitigation and addressing³³⁷ or other end-of-the-spectrum concerns over postcode lotteries and inequities in access to the fruits of therapeutic innovation.

Public awareness of many novel treatment paradigms is low regarding their existence and availability, importance, risks and benefits. For example, most members of the public do not know what phages are.¹²⁴

In areas like chrono-care, patients should be informed about the importance of timing in their treatments, which could improve adherence and outcomes. There is also a need to address transparency in relation to safety concerns and the current state of science with regards to some novel treatment paradigms, also to combat misinformation. For example, one of the key barriers to the future use of mRNA vaccines – whether for seasonal viruses and pandemic prevention or the treatment of conditions like HSV-1 and HIV – is the public acceptability and willingness to be vaccinated. There was a rapid proliferation of information about vaccines during the COVID-19 pandemic,

which also risks misinformation about the safety of vaccines. This is a common factor in vaccine hesitancy, which reduces the overall effectiveness of vaccination policies. To get the best out of mRNA vaccine technologies requires more understanding of what informs vaccine hesitancy and which means are best for addressing it in the wider population.

There are also some public concerns regarding perceptions of health and disease (e.g. weight-loss) and approaches to wider social determinants of health. Using GLP-1 agonists for weight loss has also been criticised for addressing weight loss without looking at the broader context of nutrition and public health.³³⁸

Chapter 5. Concluding remarks

This report has identified key opportunities for the NHS to embed novel treatment paradigms into the NHS as part of wider reform efforts being pursued through government work on the NHS 10-Year Plan.

Progress with novel treatment paradigms requires careful strategic planning and investments into supportive physical, data and IT infrastructure, workforce capacity and skills, enabling NHS leadership, R&D governance and regulatory innovation, collaborations, patient and public involvement and engagement. While there are no 'immediate and quick fixes', there are a plethora of opportunities to take impactful steps in the right direction. There is an opportunity cost of not acting to support both the development and implementation of key transformative novel treatment paradigms. Failure to rise to the challenge of transforming treatment approaches in the NHS could come at a significant cost to care quality, safety, efficiency and effectiveness.

Effective policy to realise the potential of novel treatment paradigms for the NHS requires both a visionary strategy and an actionable implementation plan. The nature and pace of scientific and technological advances we have discussed in this report, including the convergence of advances across diverse medical innovation fields (e.g. biology, engineering, computer science), have created a fertile platform for transformation efforts. All transformation efforts entail some upfront investment. It will be important to ensure that short-term firefighting priorities to catch up on the most urgent challenges the NHS faces (such as reducing waiting times for care and overcrowding of emergency departments)

do not come at the expense of overlooking investment in and actions to support a longer-term, bold vision for NHS excellence and sustainability, including novel treatment paradigms.

This report has illustrated the importance of novel treatment paradigms in terms of both current impact and future potential. We have shown how novel treatment paradigms building on advances in genomics, multi-omics and synthetic biology can support *more effective treatments* in areas of high health burdens like cancer or high neglect, such as some rare blood disorders. We discussed the potential of scaling novel approaches such as pharmacogenomics to *reduce the wastage of resources* on therapies that cause adverse drug reactions or don't work for some patients. We also discussed advances in areas like nanomaterials that are allowing for more *precisely targeted drug delivery*. We shed light on how novel therapeutic approaches offer hope and potentially *new ways to treat conditions for which there are currently limited options*, for example, with gene editing technologies for hereditary conditions like muscular dystrophy and transthyretin amyloidosis (a rare condition that causes damage to vital organs and tissues like the heart and nerves); epigenetic therapies for cancer, heart disease and dementia; mRNA vaccines for some cancers; and functional restoration technologies to enable patients to recover abilities they have lost or do not have such as hearing, communication and movement. We provided examples of the transformative potential of novel treatment approaches to *reduce the need for repeated interventions and hospitalisation*, such as through long-acting

cancer therapies, potential improvements and wider applications of regenerative medicine in areas like bone repair and hip replacements, and novel biologics like monoclonal antibodies as long-acting treatments for some respiratory conditions. We discussed how novel digital technology-enabled paradigms could *improve options for and access to care in particularly stretched NHS services* like mental health, how next-generation biologic drugs and drug formulations can *help tackle major public health challenges* like obesity and the potential of alternative approaches to antibiotics such as phages and monoclonal antibodies to help in the fight against antimicrobial resistance. We also considered areas where science and technology advances are comparatively more nascent (like smart pills and the microbiome) but where investments in research and innovation could potentially open up new treatment frontiers for conditions like chronic autoimmune and inflammatory conditions, cardiovascular disease, cancer and psychiatric disorders.

The insights from this report raise a series of questions that will benefit from further expert deliberation with the community of experts and decision makers, helping shape the ten-year plan and/or engage with its implementation. To make further progress, we urge discussion on topics such as:

- How to align industrial strategy and health policy incentives in determining investments into developing and adopting novel treatment paradigms. This needs to consider the unique opportunities for the UK in light of the relative size of the UK market and global position, considering prospects for being an efficient primary testbed for clinical trials while

ensuring innovative access and pricing arrangements.

- How to prioritise short, medium and long-term actions to ensure a permissive ecosystem of support mechanisms along the seven domains we have identified in this report, considering what is most needed and feasible to enact.
- How to support the development and adoption of novel treatment paradigms in ways that can address rather than exacerbate inequalities.
- How to align investment into novel treatment paradigms into wider efforts to improve care pathways, including in terms of links to diagnosis and prevention of deterioration (as part of a commissioning approach that focuses on solutions across the care pathway).
- How to deliver care pathways where the impact of novel treatment paradigms can be enhanced through complementary public health and behavioural interventions, including those targeting wider social determinants of health.
- How to ensure that short-term priorities and financial pressures do not mask the immense potential in embedding innovation in the NHS for longer-term sustainability and excellence in care.

Finally, there is a need for further research and stakeholder engagement to consider where learning from international practices could help inform tailored actions relevant to progress in different novel treatment paradigm areas. Any lessons learnt from international practice should be considered relevant to the UK context.

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